The Role of Entrepreneurial Ecosystems in Mediating the Relationship Between Knowledge Economy and Sustainable Development in Saudi Arabia

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Abstract: - This research examines how entrepreneurial ecosystems shape the relationships among the components of the knowledge economy and the outcomes of sustainable development in Saudi Arabia. Knowledge-Based View, Dynamic Capabilities Theory, and Ecosystem Theory guide the research. Using the Partial Least Squares method of Structural Equation Modeling and survey data of 384 respondents in the Vision 2030 economic regions, ten hypotheses were tested. The findings indicate that the development of the knowledge economy ($\beta = 0.785$), government policy ($\beta = 0.246$), and investment in R&D ($\beta = 0.563$) have a direct, positive impact on economic development, whereas the development of human capital and technological advancements has no impact. The study also determined that entrepreneurial ecosystems, significantly mediate the effects of human capital ($\beta = 0.209$, $p = 0.043$), R&D investment ($\beta = 0.369$, $p = 0.004$), and government policy ($\beta = 0.175$, $p = 0.080$). From the study, the development of entrepreneurial ecosystems is the most important mechanism for coordinating knowledge to achieve sustainable development in transitioning economies.

Key-Words: - Entrepreneurship Ecosystems, Knowledge Economy; Partial Least Squares Structural Equation Modeling (PLS-SEM), Sustainable Development, Saudi Arabia; Human Capital, R&D Investment, Government Policies; Vision 2030

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1 Introduction

Economic globalization, which integrates interdependent knowledge-based activities, entrepreneurial innovation, and sustainability goals, requires conceptual tools that represent knowledge production in relation to sustainability. Entrepreneurship ecosystems are seen as essential mechanisms that knowledge-based economies use to achieve inclusive and sustainable economic growth [1], [2], [3].

An entrepreneurship ecosystem consists of an adaptable network of government agencies, financial intermediaries, universities, research and development institutes, and entrepreneurial actors, and, in many cases, it also includes private sector firms, enabling innovation and competitive advantage. Ecosystems provide physical and institutional structures for knowledge sharing, innovation, resource mobilization, and the long-term diffusion of innovation in an economy to achieve sustainable outcomes [4], [5].

The transitions of resource-based economies to knowledge-based economies provides examples of how knowledge resources create sustainable economic value [6], [7]. An illustration of this is Saudi Arabia. Saudi Arabia is leading the sustainable development of its economy through the integration of entrepreneurship, innovation, and digitalization, leveraging its economic framework, natural resources, and sustainability [8], [9].

The emergence of the knowledge economy signifies a dramatic shift away from traditional resource-based inputs and toward greater reliance on intellectual capacity, research capabilities, and digital infrastructure, requiring countries to adjust their developmental paradigms [10]. The consistent and engaged production of knowledge stimulates innovation in the socio-economic sphere, thus presenting the growing opportunities that knowledge-based economies offer [11].

Thus, Saudi Arabia must integrate knowledge economy principles with sustainability goals as a strategic and developmental imperative. Finding the mechanisms that turn human capital, technology, and institutional policies into sustainability outcomes is a major challenge [12], [13]. Sustainable development—fulfilling current needs without reducing future needs—has three dimensions: economic, environmental, and social. The UN's Sustainable Development Goals (SDGs) are a universal framework for linking innovation and institutional reform to sustainability [14], [15]. The relationships between entrepreneurship ecosystems, the knowledge economy, and sustainable development are complicated and underdeveloped. R&D investments and governmental policies are structural elements, but their impact on innovation and sustainability depends on ecosystem coordination [16], [17]. Nevertheless, empirical research on how ecosystems mediate these frameworks is lacking, particularly in developing and transitional economies [18], [19], [20]. Prior research has focused either on the sustainability of the knowledge economy or on the innovation in entrepreneurship ecosystems. However, little research has examined how ecosystems mediate knowledge components like human capital, government incentives, and R&D investment into sustainable outcomes [21], [22], [23]. The absence of empirical evidence for the mediating role of ecosystems is particularly relevant for developing and transitioning economies, where institutional structures are in formation, and ecosystem development is uneven. [24], [25], [26]. Recognition of this gap will inform policy, innovation, and entrepreneurship support programs aimed at reducing the knowledge and sustainability divide. [27], [28], [29].

Following this rationale, this study proposes and empirically validates a theoretical framework that identifies entrepreneurship ecosystems as mediators between knowledge economy components and sustainable development outcomes. A systematic literature review and quantitative analysis using PLS-SEM tested ten hypotheses across several dimensions [30], [31], [32], [33]. This research (1) constructs a theoretically integrated model that explains how ecosystems mediate the knowledge-sustainability relationship; (2) empirically validates the model in the Saudi context; (3) identifies the mediation pathways; and (4) derives policy recommendations for Vision 2030. This study will show how transitioning economies can leverage their knowledge resources through entrepreneurship ecosystems to achieve sustainable and inclusive economic growth [34], [35], [36].

2 Literature Review and Hypothesis Development

2.1 The Knowledge Economy: Foundations and Characteristics

The knowledge economy represents a paradigmatic shift in the logic of development; as such, it is an economy based on information, knowledge, and intellect, replacing natural resources and ultimately value and economic growth [37]. The knowledge economy utilizes ICT strategically, for example, in enhancing learning, innovation and productivity across many sectors and demographics [37].

A knowledge-based economy can improve environmental quality through innovation and clean technologies, which combine the elements of digitalization with sustainability goals [38], however, there are no guarantees of a positive correlation between education, innovation, and growth, as unequal access to education and low-quality education can limit development [39]. Successful transitions will depend upon partnerships, digital inclusion, and institutional reform that promotes both innovation and inclusiveness.

More recent studies have indicated that the increased application of data-driven innovation and digital technologies leads to improved resource efficiency and environmental performance; as such, they reinforce the relationship between technological advancements and sustainable development [40], [41]. As such, the knowledge economy must be structured around the three mutually reinforcing elements of technology, innovation, and sustainability [42].

2.2 Human Capital as a Driver of Sustainable Development

The key role in transforming knowledge assets into sustainable results is to create the "human" capital, which can provide the intellect and creativity needed to produce innovation and long-term economic growth [43] and support the progression of an organization's competency and an economy's flexibility toward sustainability requirements [44].

Development of human capital is aligned with the overall goals of sustainability through improvement of quality, equity, and access to lifelong learning within education [45], [46]. There are recent studies indicating that there needs to be a framework embedded in education systems that includes sustainability and innovation principles to assure education systems contribute to both environmental and social equity [47]. Therefore, the capacity of human capital to aid in sustainable development will depend on two things: the capacity of producing knowledge and the ability of an ecosystem to turn that knowledge into innovation.

2.3 Technological Advancements and Sustainability Implications

In knowledge-based economies, technological advancement can be viewed as both enabling sustainable development and limiting it. Technological advancements support the transition to renewable energy sources, green production methods, and increased efficiency of material usage [48], [49], [50], yet technological advancements are insufficient for ensuring long-term sustainability - without institutions coordinating the technology, environmental efficiency gains will be limited [51].

Artificial intelligence, blockchain, and the internet of things (IoT) can bring disruptive innovations that are sustainable, yet their net-positive long-term impacts depend on advanced ecosystem-level mechanisms that foster the spread of these technologies and ensure their responsible use [52]. Thus, from a broader perspective, sustainable technological advancement depends on the development of sustainable technologies and the ecosystems that sustain their development and responsible use.

2.4 Government Policies and Incentive Mechanisms

Effective government policy is also an important factor in fostering a sustainable environment in knowledge economies by developing the framework of incentives and regulation, as well as the framework of innovation for business to develop sustainably; effective policies will foster environmentally conscious production processes, community involvement, and responsible consumerism [53], [54].

Fiscal management strategies and governance are strategic elements in creating an economically diversified industry while increasing environmental stewardship [55], [56], further, it has been found that policies which address issues of social justice, resource conservation, and institutional accountability are essential in achieving sustainable growth over time [57]. When governments establish a cooperative framework of policies across all tiers, they not only reinforce ecological systems but also amplify the knowledge economy's role in sustainable development.

2.5 Research and Development (R&D) Investments

Investment in Research and Development (R&D) propels both the growth of new innovations and the attainment of enduring competitive advantage. [58]. By promoting technological advancement, R&D stimulates equitable economic growth as well as enhances the quality and effectiveness of national innovation systems [59], [60], [61], [62].

For R&D to promote sustainable development objectives, these investments should emphasize environmentally friendly and socially benefit-oriented innovation, with cooperation between universities, firms, and Policymakers. The conversion of R&D output to sustainable development will be dependent upon effective knowledge transfer mechanisms and an ecosystem supporting the transition from product development to scale and commercialization [61].

2.6 Entrepreneurship Ecosystems: Components and Functions

An Entrepreneurial Ecosystem is an interconnected web of Institutions & Resources that allow for entrepreneurial activities & innovation to occur. The components of an entrepreneurial ecosystem are as follows: Financial Infrastructure, Human Talent, Incubators/Accelerators, and Regulatory

Environment. The factors of Access to Capital, Skilled Labor Pool, Mentorship, and Favorable Policy Conditions define how strong an entrepreneurial ecosystem is [63], [64], [65]. The mentioned components when synergized facilitate the creation of the ecology of Sustainable Venture Creation and the accelerated diffusion of Innovation.

2.7 Entrepreneurship Ecosystems and Sustainable Development Linkages

Entrepreneurship ecosystems are frameworks of knowledge, innovation, and sustainability bridging the public (policy), private (business), and research (science) sectors [66], [67]. Entrepreneurship ecosystems facilitate the flow of resources from finance, human capital, and technology toward sustainable business practices through the coordination of these resources.

Researchers have shown that at the level of the ecosystem, governance and coordinating mechanisms can be aligned with the diversity of stakeholders toward sustainability objectives [68]. Entrepreneurship ecosystems are required to be adaptive in response to technological and environmental changes in order to remain inclusive over time and resilient. This ability to be adaptive is the basis for their role as mediators between the knowledge-based economy and sustainable development.

2.8 Theoretical Framework and Research Model

In this part, we discuss three underlying theories for analyzing Figure 1 (Appendix).

1. Dynamic Capabilities Theory [11]: addresses how organizations reconfigure resources to respond to change.
2. Ecosystem Theory [4] explains relational interdependencies among the actors that promote entrepreneurship.
3. Knowledge-Based View [10]: considers some knowledge assets to be critical resources for enduring benefit.

All three theories help to elucidate how the entrepreneurship ecosystems reproduce the knowledge economy's elements—human capital, technology, policy, and R&D—into sustainable outcomes. Knowledge transfer, innovation scaling, and alignment of institutions are the routes through which ecosystems accomplish this. [69], [70].

Hypothesis Development

Based on the proposed model in Figure 1 (Appendix), the study tests both direct and mediating effects:

Direct Effects

- H1: Knowledge economy development positively affects sustainable development.
- H2: Human capital positively affects sustainable development.
- H3: Technological advancements positively affect sustainable development.
- H4: Government policies and incentives positively affect sustainable development.
- H5: Research and development investments positively affect sustainable development.

Mediating Effects

- H6: Entrepreneurship ecosystems mediate the relationship between knowledge economy development and sustainable development.
- H7: Entrepreneurship ecosystems mediate the relationship between human capital and sustainable development.
- H8: Entrepreneurship ecosystems mediate the relationship between technological advancements and sustainable development.
- H9: Entrepreneurship ecosystems mediate the relationship between government policies and sustainable development.
- H10: Entrepreneurship ecosystems mediate the relationship between research and development investments and sustainable development.

3 Methodology

3.1 Research Design and Analytical Approach

This study uses a cross-sectional design of a quantitative nature to analyze how the intermediary role of entrepreneurship systems affects the relationship between the elements of the knowledge-based economy and the results of sustainable development. A positivist framework with PLS SEM (Partial Least Squares — Structural Equation Model) was used. PLS SEM is best suited for exploratory research that has complex relationships between variables and does not follow normal distribution patterns of data and helps in solving mediation analyses [71].

The methodology was organized into four consecutive phases: (1) a comprehensive literature search to develop the theoretical foundation; (2) developing instruments and expert validation; (3) collecting data via surveys across multiple channels; and (4) conducting empirical testing through evaluating measurements and the structural models. This study employed both measurement model assessment (evaluating reliability and validity) and structural model assessment (testing hypotheses and analyzing mediation) to ensure a strong robustness and empirical validity.

3.2 Sampling Strategy and Participant Selection

This research concentrated on all participants involved in the knowledge economy and the entrepreneurship ecosystem in Saudi Arabia. Stratified random sampling was employed as the methodology to select the respondents. Those included in this study were policymakers, scholars, executives, entrepreneurs, and innovation intermediaries who worked directly within the knowledge economy and the entrepreneurship ecosystem in the Vision 2030 aligned economic regions of Al Jouf, Hail, and the Northern Border Areas.

A participant would be selected if he/she had at least 3 years of work experience and/or participated in the knowledge economy or the entrepreneurship ecosystem. This stratification among the public, private, and academic sectors helped increase external validity and generalizability of the results.

3.3 Questionnaire Development and Validation

Research tools were developed as part of a sequence based on several literature reviews; they were also reviewed by experts and pilot tested as part of the process of construct validation. In addition to being tested with valid research instruments, each construct was measured with a multi-item Likert-type scale (from 1-5) where 1 is "strongly disagree" and 5 is "strongly agree", to maintain both construct validity and content validity. Table 1 (Appendix) summarises the study variables, their literature sources, the number of items per construct, and the measurement statements used to operationalise each construct.

Fifty participants were pilot tested, as well as five academics and three industry experts on entrepreneurship, knowledge economy, and sustainability, to evaluate a questionnaire. Their feedback led to minor improvements in the clarity and contextual relevance of the questionnaire. Fifty participants piloted testing, which also demonstrated that the questionnaire had high reliability (α Cronbach > 0.8) and readability and required slight wording changes to improve the scales' balance.

3.4 Data Collection Procedures

Surveys were completed from March to June 2024 using the internet (60%), in-person (25%), and over the telephone (15%) to include as many potential respondents as possible and to minimize non-response bias.

In order to ensure that there would be no error across methodologies, all data collectors received training and each participant used the same documentation and/or surveys during their interviews or correspondence via the internet.

I ensured that I adhered to the ethical guidelines for social research and the Institutional Review Board's requirements for social research. I also obtained informed consent from each participating individual, collected their data, anonymized and safely stored it, and aggregated it.

All participants had an impressive response rate of 68% in the survey. The interview response rate was the highest at 78%.

3.5 Sample Characteristics

The sampled 384 respondents have been proportioned for PLS-SEM and are thus statistically powerful enough for the analysis [71]. The range of multiple professions and demographics strengthens external validity. Table 2 (Appendix), representative demographics of the sample, distributed by gender, age, education, and years of experience, are reported across various fields and organizations of different sizes.

3.6 Data Analysis Techniques

Data analysis was performed utilizing SmartPLS 4.0, adhering to the prescribed two-step methodology for PLS-SEM [71].

1. Measurement Model Assessment:
   - Indicator reliability: Item loadings > 0.70.
   - Internal consistency reliability: Cronbach's Alpha and Composite Reliability > 0.70.
   - Convergent validity: Average Variance Extracted (AVE) > 0.50.
   - Discriminant validity: Evaluated using the Fornell–Larcker criterion and the HTMT ratio (<0.85).
2. Structural Model Evaluation:
   - Bootstrapping with 5,000 resamples was used to estimate path coefficients, t-values, and bias-corrected confidence intervals.
   - Mediation effects were tested using the specific indirect effects approach, verifying significance for each hypothesized pathway.
   - Model fit was assessed via Standardized Root Mean Square Residual (SRMR),

Normed Fit Index (NFI), and Goodness-of-Fit (GoF) indices.

SRMR values slightly exceeding 0.08 were interpreted as acceptable, following [71], given the model's complexity and formative nature of several constructs. The overall evaluation confirmed satisfactory model reliability, validity, and explanatory power.

4 Results

4.1 Measurement Model

Table 3 (Appendix) presents the reliability and convergent validity scores of the Human Capital (HC), Technological Advancements (TA), Government Policies and Incentives (GPI), Research and Development Investments (RDI), Economic Sustainability (ES), Environmental Sustainability (EnvS), Social Sustainability (SS), and the Entrepreneurship Ecosystem (EE) Constructs. All constructs have Cronbach's alphas and rho_A values greater than 0.70, suggesting positive reliability [71]. Figure 2 (Appendix) and Table 3 (Appendix) (Factor Loadings) suggest that all standardized loadings are greater than 0.70 and all average variance extracted (AVE) values are greater than 0.50, suggesting that the items measure the construct's validity and that each construct accounts for more than half of the variance in the indicator items. Table 4 (Appendix) shows that all HTMT ratios are below 0.85, supporting the discriminant validity of all constructs. Table 5 (Appendix) of the Fornell–Larcker criterion supports the argument of discriminant validity. This indicates that the square root of the average variance extracted is greater than the inter-construct correlations, suggesting that all the constructs are conceptually and empirically distinct [71].

4.2 Model Fit (PLS-SEM Diagnostics)

Table 6 (Appendix) summarizes global fit indices. SRMR is 0.112 (saturated) and 0.103 (estimated). While values < 0.08 are typically preferred, we interpret these SRMR values as acceptable for this exploratory, multi-construct model in PLS-SEM, given the model's complexity and mediation structure. Discrepancy measures (d_ULS, d_G) improve in the estimated model, and NFI ≈ 0.94 indicates a generally good fit. High χ^2 values are expected with large samples and complex models, so we rely primarily on PLS-SEM reliability/validity diagnostics and the bootstrapped path estimates for inference.

4.3 Structural Model (Direct and Indirect Effects)

Table 7 (Appendix) presents the results of the hypothesis tests using standardized coefficients (β), standard deviations, t-values, and p-values. To enhance interpretation, we will identify each path by its constructs instead of referring to the code (H1-H10) only.

Direct effects.

- Knowledge Economy → Sustainable Development (H1): $\beta = 0.785$, $p < 0.001$ (supported).
- Human Capital → Sustainable Development (H2): $\beta = -0.005$, $p = 0.972$ (not supported).
- Technological Advancements → Sustainable Development (H3): $\beta = 0.057$, $p = 0.696$ (not supported).
- Government Policies & Incentives → Sustainable Development (H4): $\beta = 0.246$, $p = 0.024$ (supported).
- R&D Investments → Sustainable Development (H5): $\beta = 0.563$, $p < 0.001$ (supported).

Mediating (indirect) effects via Entrepreneurship Ecosystem.

- Knowledge Economy → EE → Sustainable Development (H6): $\beta = 0.128$, $p = 0.282$ (not supported).
- Human Capital → EE → Sustainable Development (H7): $\beta = 0.209$, $p = 0.043$ (supported).
- Technological Advancements → EE → Sustainable Development (H8): $\beta = 0.081$, $p = 0.521$ (not supported).
- Government Policies & Incentives → EE → Sustainable Development (H9): $\beta = 0.175$, $p = 0.080$ (marginal, supported at the 10% level).
- R&D Investments → EE → Sustainable Development (H10): $\beta = 0.369$, $p = 0.004$ (supported).

Note. *$p < 0.05$ = significant; $p < 0.10$ = marginal significance.

The knowledge economy, government policy, and R&D positively affect sustainable development. Various facets of technology and human capital don't show direct effects; however, human capital has a positive indirect effect through the entrepreneurship ecosystem, suggesting a partial mediation effect. This effect is selective: with greater channeling of human capital, policy, and R&D toward sustainability and less of technology and the knowledge economy. From a practical standpoint, policy and R&D funding are most efficiently directed through ecosystem capabilities (i.e., collaboration platforms and commercialization support), and human capital investment is directed through the ecosystem most quickly, turning skills toward sustainable innovation.

5 Discussion

5.1 Theoretical Contributions

The results from this study have meaningful theoretical implications at the nexus of the knowledge economy, entrepreneurship ecosystems, and sustainable development. It supports the theoretical proposition that entrepreneurship ecosystems serve as fundamental mediating instruments in converting knowledge assets into sustainable development outcomes. This not only supports the ecosystem theory but also the theory of dynamic capabilities.

The knowledge economy and sustainable development have a strong direct relationship ($\beta = 0.785$, $p < 0.001$), which reinforces the proposition that knowledge economy systems help create structures for sustainable outcomes. This is also in agreement with the work of [10], which proposes that the knowledge economy is a system in which the main sources of competitive advantage exist, are, and should remain, in the domains of intellect and innovation. This system contrasts with traditional models, which focus mainly on resources.

However, the differentiated effects among the components of the knowledge economy reveal an important theoretical nuance. R&D investments ($\beta = 0.563$, $p < 0.001$) and government policies ($\beta = 0.246$, $p = 0.024$) present substantial direct impacts on sustainable development. However, neither human capital nor technological developments have a direct, substantial impact. This indicates that an abundance of knowledge assets is inadequate in the absence of institutional mechanisms and ecosystem-level stipulations that promote the diffusion of knowledge, cooperation, and transfer of innovation. This result, therefore, contradicts a linear model of knowledge and sustainability and supports calls for integrated models of knowledge and sustainability that take account of institutional mediation and system-wide coordination [12], [67].

The study's unique theoretical contribution lies in the selective mediation of the relationships between the characteristics of an entrepreneurial ecosystem and the three categories of factors considered. The evidence that ecosystems mediated the relationships for human capital ($\beta = 0.209$, $p = 0.043$), government policies ($\beta = 0.175$, $p = 0.080$), and R&D investments ($\beta = 0.369$, $p = 0.004$) but did not mediate the relationships for technological advancement or the knowledge economy as a whole demonstrates the heterogeneity of the effects of ecosystems on these various resource categories. This finding supports the "ecosystem-as-a-system" view [4], [67], where an entrepreneurial ecosystem integrates, coordinates, and transforms various forms of resources into common outcomes.

In terms of dynamic capability theory [11], the varying degrees of mediation are indicative of ecosystems developing capabilities that facilitate the conversion of different types of knowledge into sustainable innovations. For example, R&D and policy-related knowledge can be converted into sustainable innovations through the development of capabilities by ecosystems, whereas technological infrastructure-related knowledge may need further institutional development before it will have a similar effect. In particular, the high degree of mediation found for R&D investment is consistent with [21], who argue that ecosystems function as knowledge orchestration platforms, connecting research outputs with sustainability applications driven by markets.

5.2 Practical Implications

The results of this study provide several important implications for policymakers, ecosystem architects, and entrepreneurs who are working in emerging transition economies like Saudi Arabia.

The first finding regarding the dual role of government policy and incentives shows that both the direct ($\beta = 0.246$, $p = 0.024$) and indirect ($\beta = 0.175$, $p = 0.080$) roles of ecosystems point to the usefulness of integrating policy measures into an entrepreneurial ecosystem to enhance the impact of government incentives. This suggests that policymakers move away from single regulatory interventionist tools and, rather, focus on holistic ecosystem policy frameworks that foster partnerships among universities, startups, and innovation intermediaries.

The findings show that building a strong entrepreneurial ecosystem is one of the most effective ways to achieve the sustainability and diversification targets of Saudi Arabia's Vision 2030. The government should prioritize strengthening the entrepreneurial ecosystem by enhancing incubation, innovation, and funding mechanisms and by transitioning knowledge-based assets into sustainable, scalable businesses.

Secondly, through direct, positive, and observable impacts, the results showed the relevance of R&D investments ($\beta = 0.563$; $\beta = 0.369$) to resource allocation and the development of the National Innovation policy. This means that in the Saudi context, the R&D investments should be backed by initiatives that improve the knowledge flow and the commercialization of the knowledge—e.g., university-industry collaboration, open innovation, and the sustainability accelerators.

Thirdly, the indirect impact of the effect of mediation of the ecosystems on human capital (β = 0.209, p = 0.043) demonstrates the necessity to incorporate human capital investments, as it relates to mediation of both entrepreneurship and the sustainability continuum. Consequently, human capital investments should be complemented by programs that enhance participants' skills in entrepreneurship, innovative management, and sustainability. This will better position participants to engage in sustainable economic practices. Moreover, universities and research institutions are in the best position to be ecosystem anchors that integrate citizens and human capital participants into innovation ballooning, thereby accelerating the use of sustainable practices.

Finally, the lack of a mediation effect of the technological advancements indicates that ecosystems are still in the early stages of development and are yet to provide the appropriate frameworks that integrate the technological innovations and the processes of diffusion/adoption. To resolve this challenge, the gap in ecosystems should be improved through the implementation of numerous directed ecosystem development actions, including integrated technology-transfer systems, digital innovation spaces, and sustainability-focused incubators.

5.3 Contextual Implications for Transitioning Economies

These results demonstrate the significance of resource-dependent economies transitioning into diversified economies while implementing a sustainability agenda. We demonstrate that merely possessing knowledge resources does not guarantee sustainable development. Rather, it is the interaction between knowledge generation and ecosystem maturation that demonstrates successful transition.

Therefore, transition economies must implement two-pronged strategies in their developmental pursuit—both enhance their knowledge infrastructure (education, R&D, and technology) and develop an environment for entrepreneurs to utilize these knowledge resources.

The findings also illustrate how the role of ecosystems in the economy mediates the relationships of human capital and policy and implies a cultural perspective of the relationship between ecosystems and institutions/behavior. Ecosystems facilitate institutional and behavioral changes that influence employees' perspectives of traditional employment to one of innovation-driven/sustainability-oriented entrepreneurialism. Therefore, government entities in transitioning economies will be successful in creating adaptive, learning-based environments through facilitating the ecosystem by regulating but empowering entrepreneurs to learn, adapt and innovate.

5.4 Limitations and Future Research Directions

The study's empirical contributions notwithstanding, it has several important limitations with respect to the nature of follow-up or additional work. One drawback of this research is the inability to establish a cause-and-effect relationship owing to the cross-sectional design; hence, a longitudinal research design is preferable to capture the changing dimensions of knowledge-ecosystem-sustainability, especially as technology and policy evolve rapidly.

Additionally, the research's geographical boundary poses a constraint, as it is limited to Saudi Arabia. Although the research contributes to knowledge of entrepreneurial ecosystems in a singular context, its outcomes have limited relevance to the global context. Thus, entrepreneurial ecosystem frameworks from other countries, especially those in emerging economies in Asia, Africa, and Latin America, would be valuable.

Subsequent research is encouraged to delve into the inner workings of entrepreneurial ecosystems to understand how knowledge and sustainability are mediated and to identify which characteristics (trust in the system, financing, and collaboration) are conducive to such impact.

Furthermore, research integrating qualitative and quantitative approaches, such as longitudinal case studies, comparative ecosystem mapping, and social network research, is encouraged to examine how varied forms of ecosystem coordination, knowledge spillovers, and governance frameworks respond to efforts to promote sustainable innovation.

Lastly, assessing moderating variables (e.g., cultural values, digital maturity, and policy and regulatory coherence) will shed even more light on how entrepreneurial ecosystems function as adaptive mediators of the knowledge-sustainability nexus, while accounting for the different degrees of development as stages of the economy.

6 Conclusion

Dynamic Entrepreneurial Ecosystems provide a solution to the puzzle identified in the analysis of the individual elements of the knowledge economy and Sustainable Development. The research presents evidence for the existence of new paths of converting knowledge into Sustainable Outcomes, and intensively examines the relationship between these new pathways by developing and testing an appropriate conceptual framework located at the interface of Dynamic Capabilities Theory, Ecosystem Theory and Knowledge-Based Theory. This study provides insight into the mechanisms by which Transitioning Economies (TEs) use ecosystems to convert Intellectual Resources into Sustainable Value.

Research outcomes show that the development of the knowledge economy at large, the corresponding governmental policies, and R&D funding have direct positive effects on sustainable development. On the contrary, the effects of human capital and technological development on sustainability are more tangible when there is ecosystem intermediation. The findings also show that entrepreneurship ecosystems partially mediate the impacts of human capital, government policies, and R&D investments, which points to the differentiated—not uniform—knowledge dimension impacts.

The study adds to the body of knowledge by showing that entrepreneurship ecosystems are adaptive coordination systems that assemble and integrate knowledge assets toward sustainability and, therefore, extend the literature on ecosystems as collective-level dynamic capabilities. This suggests that ecosystems can convert dormant knowledge into active innovation.

In practice, the report argues that, for sustainable development, advancing the knowledge economy should be coupled with ecosystem development rather than treated as parallel or independent endeavors. Policymakers must integrate across the siloed domains of regulatory frameworks, financing of basic research and development, entrepreneurial infrastructure, human capital development, and innovation system investments, which tend to be siloed within the entrepreneurial ecosystem and innovation system.

For Saudi Arabia's Vision 2030 and analogous national transformation programs, the report's findings point to the need for the integration of knowledge ecosystems to be designed and built for ease of innovation, collaborative governance, and sophisticated system integration to meet the sustainability and diversification goals. Supporting sustainable knowledge disposal and sustainable production, employment, and the environment requires strengthening knowledge ecosystems.

Finally, future work should examine the temporality of these relationships, first by conducting longitudinal studies within a single country and then by comparing countries. These studies will demonstrate the maturity of ecosystems, the level of developed institutions, and the existing culture, and how these determine the extent to which knowledge can be translated to sustainability. Therefore, it will allow for improving the theoretical propositions of this study and, consequently, for policymaking regarding sustainable knowledge economies.

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Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

APPENDIX

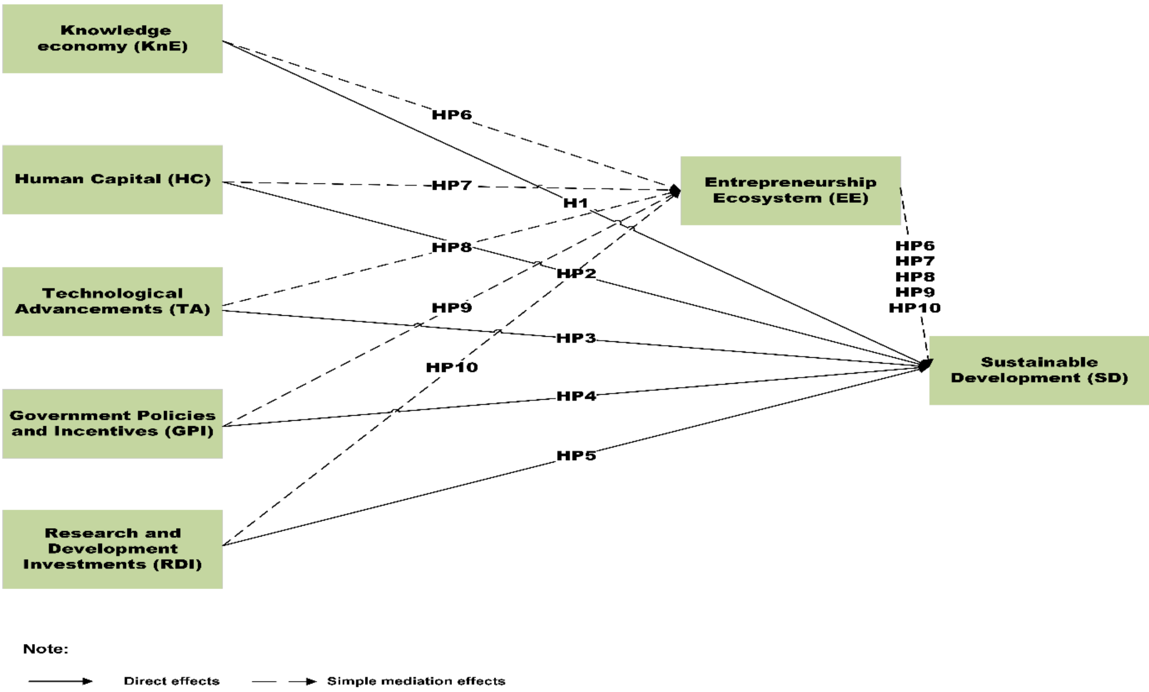

Fig. 1: Research framework.
Source: created by the authors.

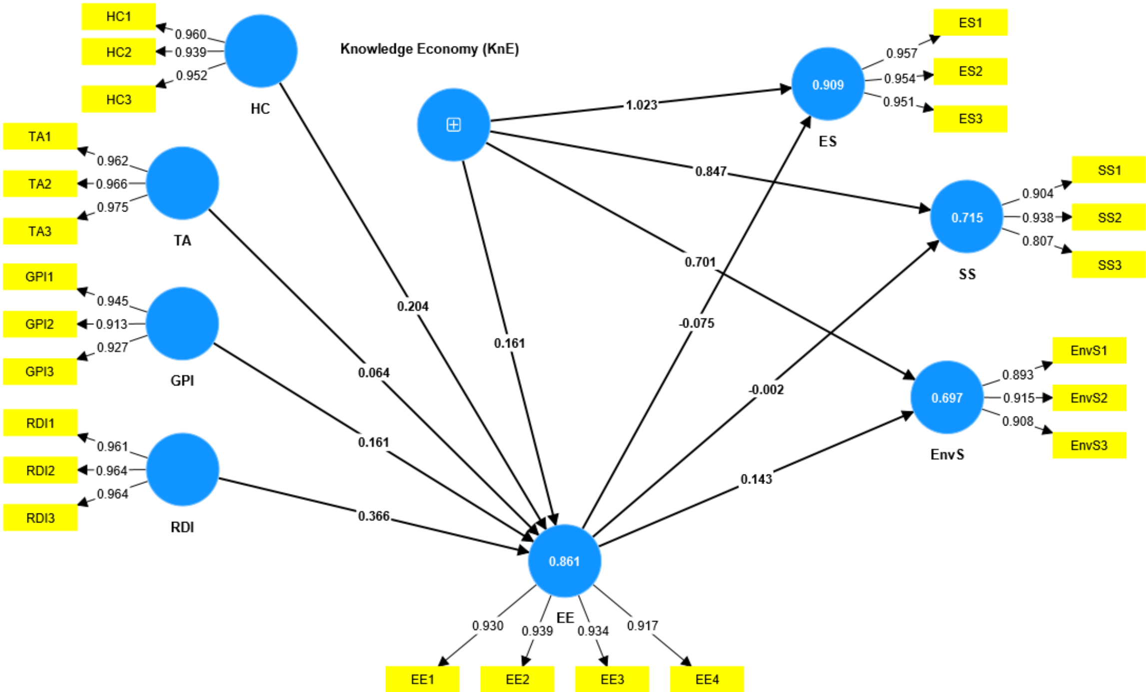

Fig. 2: Output loading of factors.
Source: created by the authors using SmartPLS 4.0.

Table 1. Study Variables, Measurement Items, Sources, and Indicators

Variables	Source	Items	Indicators (Measurement Statements)
Human Capital (HC)	[45], [44]	3	HC1: Employees regularly engage in training that supports innovation. HC2: The organization invests in ongoing learning and skill development. HC3: Workers know how to use sustainable methods.
Technological Advancements (TA)	[48], [50]	3	TA1: We adopt new digital technologies to enhance productivity. TA2: We use digital tools to make our operations more efficient. TA3: New technology helps us reach our social and environmental goals.
Government Policies and Incentives (GPI)	[53], [56]	3	GPI1: The government makes policies that support sustainable business. GPI2: Rules help businesses that are green and creative. GPI3: Public incentives motivate us to adopt environmentally responsible practices.
Research and Development Investments (RDI)	[58], [59]	3	RDI1: We consistently invest in research and development. RDI2: Resources are allocated to R&D projects focused on sustainability. RDI3: Working with other companies on research and development makes it easier for us to come up with new ideas that will last.
Economic Sustainability (ES)	[14], [15]	3	ES1: The things we do help the economy stay stable and grow over time. ES2: Resources are managed efficiently to maintain profitability. ES3: We keep the economy strong with our business practices.
Environmental Sustainability (EnvS)	[14], [15]	3	EnvS1: We are compliant with regulations regarding environmental protection. EnvS2: We are committed to reducing our environmental footprint. EnvS3: There is a system of management and control of waste, energy, and other resources.
Social Sustainability (SS)	[14], [15]	3	SS1: We are committed to the promotion of equality and to the elimination of discrimination. SS2: The health and safety of employees and the community are of primary concern. SS3: The organization participates in community beneficial activities.
Entrepreneurship Ecosystem (EE)	[62], [63]	4	EE1: The local ecosystem provides solid financial and institutional support for new ventures. EE2: Connectivity, networks, and partnerships among actors support entrepreneurship and innovation. EE3: Business incubators and accelerators are essential for the creation of viable businesses. EE4: The integration of ecosystem actors supports innovation and growth.

Source: adapted by the authors from the cited literature.

Table 2. Demographic Information

Category	Variable	Frequency	Percentage (%)
Gender	Male	256	66.7
	Female	128	33.3
Age	25–35 years	134	34.9
	36–45 years	152	39.6
	46–55 years	76	19.8
	Above 55 years	22	5.7
Education	Bachelor's	167	43.5
	Master's	156	40.6
	PhD	61	15.9
Experience	3–7 years	143	37.2
	8–15 years	162	42.2
	Above 15 years	79	20.6
Sector	Private	198	51.6
	Public	98	25.5
	Academic	88	22.9
Organization Size	Small (1–50)	134	34.9
	Medium (51–250)	127	33.1
	Large (>250)	123	32.0

Source: created by the authors based on survey data.

Table 3. Constructs' reliability and convergent validity.

Constructs	Items	Loadings (>0.70)	Cronbach's Alpha (>0.70)	rho_A	Average Variance Extracted (AVE) (>0.50)
Human Capital (HC)	HC1	0.960	0.946	0.948	0.902
	HC2	0.939			
	HC3	0.952			
Technological Advancements (TA)	TA1	0.962	0.966	0.967	0.937
	TA2	0.966			
	TA3	0.975			
Government Policies and Incentives (GPI)	GPI1	0.945	0.920	0.920	0.862
	GPI2	0.913			
	GPI3	0.927			
Research and Development Investments (RDI)	RDI1	0.961	0.960	0.961	0.927
	RDI2	0.964			
	RDI3	0.964			
Economic Sustainability (ES)	ES1	0.957	0.951	0.952	0.910
	ES2	0.954			
	ES3	0.951			
Environmental Sustainability (EnvS)	EnvS1	0.893	0.890	0.900	0.819
	EnvS2	0.915			
	EnvS3	0.908			
Social Sustainability (SS)	SS1	0.904	0.861	0.891	0.783
	SS2	0.938			
	SS3	0.807			
Entrepreneurship Ecosystem (EE)	EE1	0.930	0.948	0.951	0.865
	EE2	0.939			
	EE3	0.934			
	EE4	0.917			

Source: created by the authors using SmartPLS 4.0.

Table 4. Discriminant validity (HTMT Ratio)*

	EE	ES	EnvS	GPI	HC	RDI	SS	TA
EE	-							
ES	0.815	-						
EnvS	0.847	0.871	-					
GPI	0.831	0.842	0.882	-				
HC	0.838	0.820	0.837	0.826	-			
RDI	0.851	0.875	0.853	0.742	0.857	-		
SS	0.845	0.831	0.834	0.860	0.841	0.815	-	
TA	0.826	0.806	0.866	0.858	0.863	0.851	0.854	-

Source: created by the authors using SmartPLS 4.0.

*Note: *A HTMT Ratio < 0.85 is considered valid.*

Table 5. Discriminant validity (Fornell-Larcker criterion) *

	EE	ES	EnvS	GPI	HC	RDI	SS	TA
EE	0.930							
ES	0.871	0.954						
EnvS	0.791	0.806	0.905					
GPI	0.871	0.881	0.806	0.928				
HC	0.890	0.872	0.773	0.864	0.950			
RDI	0.810	0.833	0.795	0.885	0.813	0.963		
SS	0.782	0.856	0.799	0.775	0.772	0.847	0.885	
TA	0.888	0.870	0.809	0.804	0.821	0.816	0.791	0.968

Source: created by the authors using SmartPLS 4.0.

*Note: *Following the Fornell-Larcker criterion, the bold value is accepted when it exceeds its row and column values.*

Table 6: *Results of GOODNESS-OF-FIT*

	Saturated model	Estimated model
SRMR	0.112	0.103
d_ULS	2.817	2.203
d_G	1.296	1.204
Chi-square	2945.810	2922.477
NFI	0.939	0.938

Source: created by the authors using SmartPLS 4.0.

Table 7. Hypothesis testing results for direct and mediated relationships

Path	Std. β	Std. Error	t-value	p-value	Decision
Direct effects					
Knowledge Economy → Sustainable Development	0.785	0.125	6.298	< 0.001	**Supported (**p < 0.01 **) **
Human Capital → Sustainable Development	– 0.005	0.127	0.036	0.972	Not supported
Technological Advancements → Sustainable Development	0.057	0.147	0.391	0.696	Not supported
Government Policies & Incentives → Sustainable Development	0.246	0.109	2.260	0.024	**Supported (**p < 0.05 **) **
Research & Development Investments → Sustainable Development	0.563	0.155	3.623	< 0.001	**Supported (**p < 0.01 **) **
Indirect (mediated) effects via Entrepreneurship Ecosystem (EE)					
Knowledge Economy → EE → Sustainable Development	0.128	0.119	1.077	0.282	Not supported
Human Capital → EE → Sustainable Development	0.209	0.120	1.734	0.043	**Supported (**p < 0.05 **) **
Technological Advancements → EE → Sustainable Development	0.081	0.126	0.641	0.521	Not supported
Government Policies & Incentives → EE → Sustainable Development	0.175	0.100	1.752	*0.080*	**Marginally supported (**p < 0.10 **) **
Research & Development Investments → EE → Sustainable Development	0.369	0.127	2.897	0.004	**Supported (**p < 0.01 **) **

Source: created by the authors using SmartPLS 4.0.