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Analyzing the Key Drivers of Sustainable Academic Entrepreneurship: A System Dynamics Perspective

Elham Mofateh Zadeh[a], Ali Morovati Sharifabadi[a]*, Habib Zare Ahmadabadi[a], Seyed Heydar MirFakhradini[a]

[a] *Department of Management, Faculty of Humanities and Social Sciences, Yazd University, Yazd, Iran.*

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ABSTRACT

Sustainable academic entrepreneurship constitutes a fundamental pillar of sustainable academic transformation, enabling universities to align their missions with environmental, economic, and societal objectives. Although global interest in this field is rising, many universities—especially in developing countries—face institutional and structural barriers that hinder the emergence of sustainable entrepreneurial ecosystems. A comprehensive, systems-based understanding of the key drivers, interdependencies, and feedback mechanisms is essential to address these challenges. This study employs a mixed-method design, integrating meta-synthesis of scholarly literature and expert interviews to identify 25 critical factors influencing sustainable academic entrepreneurship. A system dynamics model was constructed and validated by academic stakeholders. The model was simulated using Vensim software over 60 months, and seven policy scenarios were tested, focusing on variables including entrepreneurship education, financial support, industrial experience, managerial continuity, and regulatory conditions. Simulation findings demonstrate that enhancing the quality of entrepreneurship education, expanding industrial experience among faculty and students, and implementing targeted financial incentives significantly strengthen entrepreneurial capacity and foster the development of sustainable innovation centers. Moreover, scenario-specific results indicated that integrated implementation of multiple supportive policies produced the most substantial improvements, whereas isolated interventions had limited effects. Conversely, institutional constraints—including bureaucratic complexity, inconsistent policies, and limited leadership commitment—generate strong balancing feedback loops that impede long-term growth. The most effective improvements emerged from the integrated implementation of supportive policy measures. To promote sustainable academic entrepreneurship, universities must adopt systemic and forward-looking strategies that simultaneously address structural and behavioral drivers. Findings from the policy scenarios suggest that reinforcing positive feedback loops—including education, experience, and institutional support—while minimizing counterproductive constraints maximizes idea success rates, innovation outputs, and ecosystem resilience. The proposed model offers actionable insights for policymakers aiming to align institutional transformation with sustainable development goals.

Keywords

Sustainable Academic Entrepreneurship; System Dynamics Modeling; Entrepreneurship Education; Vensim Simulation.

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*Corresponding author
Email: alimorovati@yazd.ac.ir

1. Introduction

In recent decades, entrepreneurship and the cultivation of entrepreneurial talent have become central concerns within higher education systems. The rising unemployment rate among university graduates has caused significant economic, social, and psychological consequences, including reduced self-confidence, loss of motivation, and brain drain. When graduates lack practical skills, the ability to identify market opportunities, or the creative mindset required to enter the labor market, universities cannot be said to have fulfilled their mission of empowering human capital. Today, universities are expected to go beyond theoretical instruction by creating environments that foster experiential learning, creativity, and innovation. This enables students to develop the capacity to generate employment opportunities aligned with their abilities and interests, either during or after their studies. Academic entrepreneurship has emerged as a key indicator of third- and fourth-generation universities, bridging the gap between higher education and the labor market (Guerrero et al., 2016).The concept pertains to structured activities aimed at the commercialization of knowledge, technology transfer, and the empowerment of human capital to support innovation-driven economic developmen (Breznitz and Etzkowitz , 2014). Research indicates that academic entrepreneurship is directly and significantly related to three core elements: entrepreneurship education, scientific research, and innovative activities. These elements, in turn, are indirectly linked to broader economic growth (Guerrero and Urbano, 2012). However, despite the growing body of research, several gaps remain. In particular, most studies have focused on economic outcomes, while the integration of social and environmental dimensions of sustainability within academic entrepreneurship remains underexplored. Furthermore, previous research rarely considers the dynamic interactions between multiple factors and the long-term impacts of policy interventions, limiting the ability to support evidence-based decision-making in universities. Thus, it is essential to incorporate the three dimensions of sustainability—economic, social, and environmental—into entrepreneurial planning and policymaking within academia to ensure balanced and lasting development (Fayolle and Redford, 2014). Addressing these gaps, the present study employs a mixed-method approach, combining meta-synthesis and system dynamics modeling. A systematic literature review was conducted to extract key factors influencing sustainable academic entrepreneurship, followed by the design and simulation of a conceptual model—including causal loop and stock-flow diagrams—over five years. Finally, different policy scenarios were defined and analyzed, providing a practical framework for supporting future decision-making and demonstrating the

added value of integrating dynamic modeling into academic entrepreneurship research.

2. Literature review

2.1. *Sustainable academic entrepreneurship*

Numerous studies have explored the concept of sustainable entrepreneurship, each emphasizing different aspects, including sustainable entrepreneurship, economic enterprise, environmental entrepreneurship, social entrepreneurship, and green entrepreneurship (Burzyńska et al., 2018). For example, green entrepreneurship focuses on developing products and technologies that address environmental challenges; in this case, entrepreneurial activities aim to generate profit while simultaneously considering environmental concerns (Jolink and Niesten, 2015). Recent research indicates that universities are increasingly embracing the concept of green entrepreneurship, and ecological values should be integrated into university entrepreneurial support systems (Şener et al., 2018). Social entrepreneurship in the academic context is regarded as an effort to cultivate future social entrepreneurs. University-level social entrepreneurship programs are typically designed through collaboration with communities and industry, often generating significant impact on local areas. The knowledge and skills acquired from universities—regardless of academic or cultural background—can be strategically leveraged to address social problems through innovative solutions (Roslan et al., 2020). Researchers argue that social entrepreneurship can help alleviate major social issues, including poverty, homelessness, child welfare, unemployment, racial discrimination, and unequal access to education, while also reducing criminal behavior (Kaplaperis et al., 2020). Social entrepreneurs make meaningful contributions to society by creating social value and addressing both environmental and social issues through key mechanisms, including economic recovery, employment development, innovation, and the promotion of social equity (Alden et al., 2017). In general, social entrepreneurship is considered both effective and sustainable because it prioritizes environmental and social values over purely economic ones (Kaplaperis et al., 2020). Education plays a fundamental role in motivating students to pursue social entrepreneurship, highlighting the need for targeted academic programs and supportive institutional policies (Gupta et al., 2020). On the other hand, the primary goal of entrepreneurship remains economic growth and financial improvement within society. It is now widely recognized that higher education institutions, in addition to their traditional missions of research and education, play a critical role in regional economic development (Trippl et al., 2015). The entrepreneurial university model enables institutions to actively contribute to regional development by

initiating economic, social, and environmental activities in a coordinated manner (Goddard et al., 2012).

Overall, the concept of sustainable academic entrepreneurship refers to a university model that, in addition to addressing scientific challenges facing society, government, and businesses, also fosters innovation among its members, facilitates the commercialization of academic research, and contributes to the production and dissemination of new technologies and knowledge—while simultaneously addressing the three dimensions of sustainability: social, economic, and environmental. This integration highlights the complex interactions among these dimensions, which can be effectively analyzed and simulated through system dynamics modeling.

2.2. *Review of the literature*

Studies examining academic entrepreneurship have primarily addressed topics including the role of universities in society, characteristics of entrepreneurial universities, the development of academic entrepreneurship models, entrepreneurial assessment of universities, technology transfer processes, university-government-industry interaction, the establishment of spin-offs, commercialization of academic research, and environmental factors influencing academic entrepreneurship. Today, academic entrepreneurship has become one of the most intriguing scientific domains for researchers across various countries, receiving considerable attention in recent years.

Given that the advancement of any scientific field depends on the accumulation of knowledge and the systematic review of existing research, analyzing the trends in academic output and scholarly investigations on academic entrepreneurship in recent years can provide a roadmap for future directions. In the broader field of entrepreneurship, several studies have explored various sub-domains, including entrepreneurship in family firms (López et al., 2016), international entrepreneurship (Abreu et al., 2016), social entrepreneurship (Dionisio, 2019; Rey-Martí et al., 2016), university-industry collaboration (Rybnicek, 2019), entrepreneurial organizations, entrepreneurial cognition and social constructionist approaches (Sassetti et al., 2018), ethics and entrepreneurship (Wallaster et al., 2019), and innovation and entrepreneurship (Sharma, 2019). Although numerous studies have been conducted on academic entrepreneurship and sustainable entrepreneurship individually, research at the intersection of these two—namely, sustainable academic entrepreneurship—is still limited. The few existing studies in this area primarily focus on the entrepreneurial ecosystem within universities.

In general, numerous studies have examined the impacts of universities on entrepreneurship and the indicators of academic entrepreneurship. Separately, many investigations have focused on sustainable entrepreneurship, primarily addressing the influence of entrepreneurship on sustainability and vice versa. However, there is currently no comprehensive and integrative model that consolidates valuable insights from previous research and employs a system dynamics approach to design a dynamic model of sustainable academic entrepreneurship tailored specifically for universities. Given that one of the foremost objectives of universities is to foster sustainable entrepreneurship at all educational levels and stages, dynamic modeling combined with simulation is essential and indispensable for university managers and policymakers.

3. Research methodology

This study employs a meta-synthesis approach to comprehensively identify the factors influencing sustainable academic entrepreneurship through a systematic review of existing literature. Meta-synthesis is particularly suitable for integrating findings from multiple qualitative studies, allowing the extraction and operationalization of 25 critical factors that form the basis of our system dynamics model. Meta-synthesis is a qualitative research method that critically examines and integrates findings from related and similar studies to identify new themes, thereby advancing existing knowledge and providing a broader and more comprehensive perspective on the research topic (Sattar et al., 2021). Implementing meta-synthesis involved clearly defined inclusion and exclusion criteria, a systematic search strategy, and independent review by multiple researchers to ensure reliability and minimize bias.

Subsequently, system dynamics methodology was employed for modeling and simulating relevant scenarios, with a specific focus on the interactions among key factors identified from the meta-synthesis. According to system dynamics theory, various variables within a complex system are causally linked through interacting feedback loops, which collectively form the system's structure. This structure determines the behavior of the system .The primary aim of system dynamics is to assist managers in understanding complex systems, enabling them to intervene effectively to align system behaviors with their objectives (Elsawah et al., 2020; Lane, 2023). In this study, system dynamics modeling was tailored to the context of sustainable academic entrepreneurship, providing a practical framework for simulating policy scenarios and evaluating potential outcomes. The modeling and simulation followed the iterative five-

step process outlined by Sterman (2000), which has since been refined and applied in diverse socio-technical and sustainability contexts (Elsawah et al., 2020; Lane, 2023).

1. Problem articulation to define the purpose of modeling.
2. Formulation of dynamic hypotheses leading to a conceptual representation of the complex system.
3. Development of a simulation model that translates the conceptual framework into a simulation model with equations defining the relationships among variables.
4. Model testing where simulated flows and stocks were calibrated against existing data, expert expectations, and iterative feedback from academic stakeholders to ensure the validity and credibility of the results.
5. Policy design and evaluation based on scenarios activated by changing parameters or structures to learn about the effects of such changes.

Each stage of this research involves specific methods and data analysis tools tailored to that phase, which are presented in Figure 1.

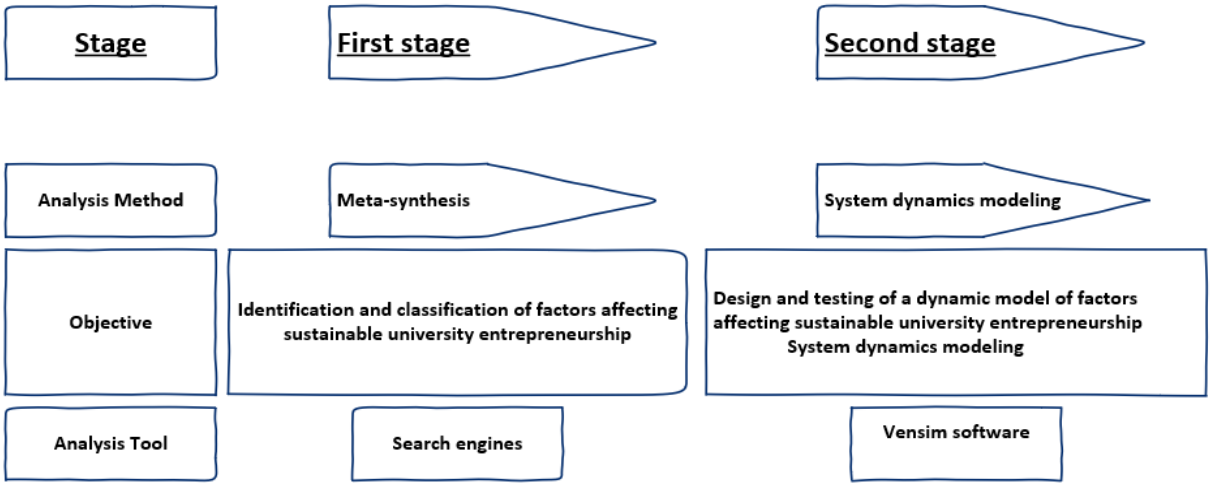

Figure 1. Research stages, objectives, methods, and analytical tools

Stage One: Extraction of Factors Influencing Sustainable University Entrepreneurship. A systematic search was conducted across multiple databases to identify peer-reviewed articles relevant to sustainable academic entrepreneurship. Scopus was the primary database, and keywords were carefully selected to capture economic, social, and environmental aspects of entrepreneurship in higher education. The following keywords were used in the search strategy:

"entrepren***" OR "spin-offs" OR "spin-offs" OR "spin-off" OR "spin off" AND "sustain***" OR "green" OR "ecol***" OR "environmental" OR "social***" AND "univers***" OR "academ***" OR "higher education" OR "educational institutes"

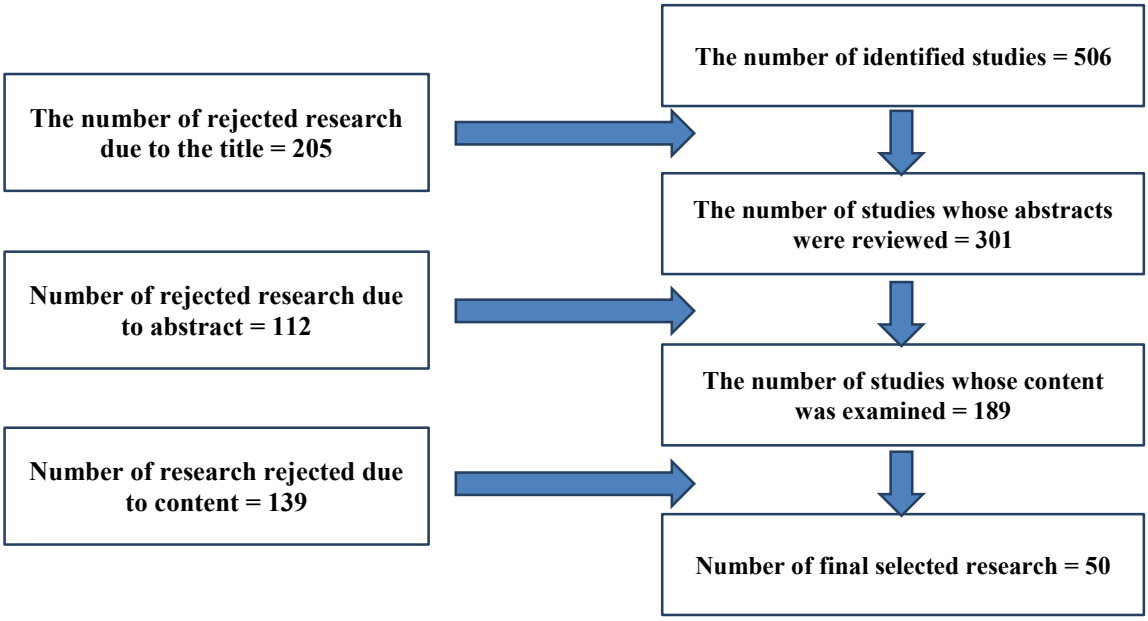

Figure 2. A summary of the search results and selection of appropriate articles

The results obtained from the literature review using the meta-synthesis approach can be seen in Table 1.

Table 1. Extraction of factors affecting sustainable university entrepreneurship development

Row	Coding	Concepts
1	▪ Concentration of decision-making at the macro level and elimination of university participation ▪ Limitations on university authority in managing resources and programs ▪ Hierarchical and inflexible structure in the higher education system ▪ Decreased initiatives and innovations of academic institutions ▪ Severe dependence of universities on central decisions	Centralization in the higher education system
2	▪ Repeated changes in university management levels ▪ Lack of stability in macro policies and long-term programs ▪ Disruption in project implementation due to management instability ▪ Decreased trust of stakeholders in the university management system	Management instability and frequent changes
3	▪ Formulating a strategy for the commercialization of academic research ▪ Supporting the commercialization of students' ideas ▪ Developing new environmentally friendly products in laboratory settings	Commercialization of environmental ideas
4	▪ The level of industry trust in universities ▪ Strengthening the interaction between industry and universities and the external environment ▪ Increasing academic interactions in national and regional spaces ▪ Signing bilateral and multilateral contracts between universities and industry ▪ A dynamic, continuous, and effective connection between universities and the industry and society, and carrying out multiple work contracts ▪ Utilizing the university's brand to attract collaboration ▪ Strategic participation of universities in major economic, environmental, and social projects	Industry-university collaboration and interaction

Row	Coding	Concepts
5	▪ Creating educational platforms for managers and university professors regarding the importance of entrepreneurship ▪ Providing entrepreneurship training programs for newly hired and less experienced professors ▪ Developing an entrepreneurial culture in the university ▪ Institutionalizing an entrepreneurial culture among university staff, faculty members, and students	Entrepreneurship culture in the university
6	▪ Lack of a centralized authority for policy-making in the field of sustainable entrepreneurship ▪ Lack of inter-organizational coordination in the design and implementation of policies ▪ Gap in specialized monitoring of academic entrepreneurial activities ▪ Need for the establishment of an independent and accountable policy-making body	Lack of a specialized policymaking body for sustainable university entrepreneurship.
7	▪ Encouraging the university to use electric vehicles, public transportation, bicycles, etc. ▪ Promoting waste recycling at the university ▪ Raising awareness among professors, students, staff, and university administrators regarding environmental issues ▪ Educating about sustainable development goals. Implementing circular economy principles at the university has positive environmental impacts ▪ Helping the university save energy and resources	Culture of Sustainability in the University
8	▪ The number of business laws related to sustainable development ▪ Making changes to academic regulations to encourage university entrepreneurship ▪ Making changes to educational policies and knowledge development to increase university entrepreneurship ▪ Reviewing existing regulations to facilitate the process of entrepreneurship development	University rules and policies
9	▪ Increase research and development in the field of sustainable entrepreneurship ▪ Establish a research and development unit at the university	Establishment of a research and development unit at the university
10	▪ Creating a curriculum system for teaching innovation and entrepreneurship ▪ Integrating entrepreneurship education with vocational training ▪ Guiding coursework projects in the direction of self-employment and entrepreneurship ▪ Strengthening the teaching capacity of professors in entrepreneurship education ▪ Incorporating entrepreneurship courses as mandatory subjects.	Entrepreneurship education at the university
11	▪ Establishing new structures ▪ Establishing professorships ▪ Creating sustainable or social entrepreneurship centers ▪ Establishing innovation centers	Establishing innovation centers at the university
12	▪ Development of information and communication technology infrastructure at the university ▪ Increasing the university's internet bandwidth ▪ Utilizing digital technology infrastructure at the university ▪ Renovation, equipping, and development of laboratories	Sustainable entrepreneurial infrastructure
13	▪ Cultural resistance to the acceptance of innovation and structural changes ▪ Traditionalism in management and academic teaching methods ▪ Fear of risk-taking and avoidance of entrepreneurial approaches ▪ Challenges in shifting the university members' attitudes towards sustainability	Traditional resistance

Row	Coding	Concepts
14	▪ Inadequate laws to protect the intellectual property of university members ▪ Lack of executive mechanisms for registering patents and trademarks ▪ Challenges in pursuing legal rights for intellectual property violations ▪ Need for a review of existing laws to cover innovations	The weakness of intellectual property protection laws
15	▪ Lack of financial and moral incentives for entrepreneurial activities ▪ Reward systems that do not align with the needs of innovation and sustainability ▪ Neglect of professional motivations in entrepreneurship development ▪ Need for designing multidimensional incentive mechanisms	Inappropriate incentive system
16	▪ Lack of direct interaction between professors and students with industrial projects ▪ Gap between university education and actual industry needs ▪ Weakness in transferring practical experience from industry to the university environment ▪ Need to develop internship programs and joint projects	Industrial experience
17	▪ Complex and time-consuming administrative processes for project implementation ▪ Slowness in approving and executing entrepreneurial plans ▪ Administrative barriers for attracting investment and collaborating with the industry	Bureaucracy in the university
18	▪ The level of financial and non-financial support from institutions for sustainable entrepreneurship in universities ▪ Financial support from institutions for student startup projects ▪ The level of government support for entrepreneurship in the country's universities ▪ Establishing an investment fund to assist newly established university companies ▪ Non-governmental financial resources through enhancing the quality of services and developing university entrepreneurship	University financial support
19	▪ Considering sustainable entrepreneurship in the university's mission statement, vision, and goals ▪ Sustainable development goals should be reflected in the university's vision ▪ The long-term and strategic perspective of university managers towards entrepreneurship and the commercialization of ideas	Sustainable Entrepreneurial Strategic Planning
20	▪ Reforming the system for recruiting and promoting professors based on sustainable entrepreneurship development ▪ Incorporating green and social criteria into recruitment tests and interviews ▪ Assessing sustainable entrepreneurship characteristics in job applicants ▪ Recruiting faculty based on the level of entrepreneurial and environmental initiatives and projects	Appropriate recruitment and hiring system
21	▪ Disconnection between executive, supportive, and supervisory bodies ▪ Lack of alignment between the goals of governmental institutions and the needs of universities ▪ Challenges in the allocation of resources and unified legal support ▪ Interference in the duties and responsibilities of related institutions	Lack of coordination among government agencies
22	▪ Ineffective metrics for assessing entrepreneurial activities ▪ Lack of attention to sustainability criteria in evaluating professors and students ▪ Deficiency in the performance-based reward system for innovation	Weakness in the performance evaluation system
23	▪ Support and commitment of management towards university entrepreneurship ▪ Commitment of senior management ▪ University managers should be supporters and committed to the processes of entrepreneurship and idea creation in the university	Commitment and support of senior management

Row	Coding	Concepts
24	▪ Risk-taking of university managers ▪ Risk-taking ▪ Willingness to take risks among managers	Risk-taking
25	▪ Strengthening financial resources and allocating budget for sustainable entrepreneurship development ▪ Allocating budget for entrepreneurial ideas ▪ Establishing a specific budget line for the development of entrepreneurial activities in the university ▪ Attracting investors to support entrepreneurial ideas	Investment in sustainable university entrepreneurship development

The input variables of the model were derived from a meta-synthesis of25key factors influencing sustainable academic entrepreneurship. The selection process followed clear inclusion and exclusion criteria, predefined keywords, and systematic search strategies to ensure both rigor and comprehensiveness. To further improve the validity of the extracted .factors, the results were reviewed and refined with input from academic experts

3.1. System dynamics approach

The objective of system dynamics modeling is to analyze the dynamic behavior of systems over time, facilitating the design of effective policies and strategies aimed at performance enhancement (Currie et al., 2018), and simulation models offer several advantages over other problem-solving methods, especially when dealing with complex systems. In an analytical solution, it may not be possible for the modeler to formulate the behavioral aspects of the system in the form of analytical equations. However, in a simulation model, virtually any system can be represented based on a set of assumptions.

3.1.1. Dynamic hypotheses

The dynamic hypothesis of this study is developed based on a systematic literature review, expert insights, and a systems thinking perspective. The core assumption is that the development of sustainable academic entrepreneurship in Iranian universities is shaped by a set of interrelated structural, behavioral, and policy-related variables that interact through complex feedback loops. The hypothesis posits that the observed sluggishness and instability in sustainable academic entrepreneurship stem from the dominance of structural barriers over reinforcing mechanisms. These structural constraints include insufficient entrepreneurial education infrastructure, inadequate financial support, limited industrial experience among faculty and students, managerial instability, weak institutional commitment, and the absence of consistent and enabling policies. In contrast, reinforcing loops can be activated by improving

entrepreneurship education, enhancing targeted financial support, strengthening university–industry linkages through industrial experience, reducing managerial turnover, fostering high-level commitment, and institutionalizing supportive regulations. These actions are hypothesized to create a reinforcing feedback system that increases idea success rates, encourages the establishment of sustainable innovation centers, and gradually transforms the academic environment into a more entrepreneurial and sustainable ecosystem. For instance, improved entrepreneurship education raises awareness and capabilities, increasing idea success rate and creating a self-reinforcing cycle of innovation. Financial support accelerates commercialization and infrastructure development, while industrial experience bridges the gap between theory and practice. Managerial stability ensures continuity of strategy and trust. Leadership commitment mobilizes resources and embeds a culture of entrepreneurship. Finally, enabling policies reduce bureaucratic frictions and promote coordinated institutional efforts. Together, these interacting variables form the foundation of the system dynamics model and are visualized through a Causal Loop Diagram in the next section.

3.1.2. Causal loop diagram

The Cause-and-Effect Loop Diagram (CLD) is presented in Figure 3, which effectively illustrates the complex causal relationships between the identified variables related to sustainable academic entrepreneurship. This diagram also shows the key reinforcing and balancing cycles in the university ecosystem. The 25 factors extracted through the meta-synthesis were operationalized as input variables in the system dynamics model. To capture both tangible and intangible aspects, each factor was mapped into causal relationships and translated into parameter values. Where empirical data were available, they were used for quantification; in cases where data were unavailable, expert judgment was employed. This approach ensured that qualitative factors—such as institutional support, entrepreneurial culture, and resistance to change—were also adequately represented in the simulation model. To enhance transparency, the assumptions of the model were clearly stated. In cases where empirical data were limited, assumptions were grounded in established findings from the literature and refined through expert consultations. This approach ensured that the model remained both empirically valid and practically feasible, while acknowledging the constraints of data availability.

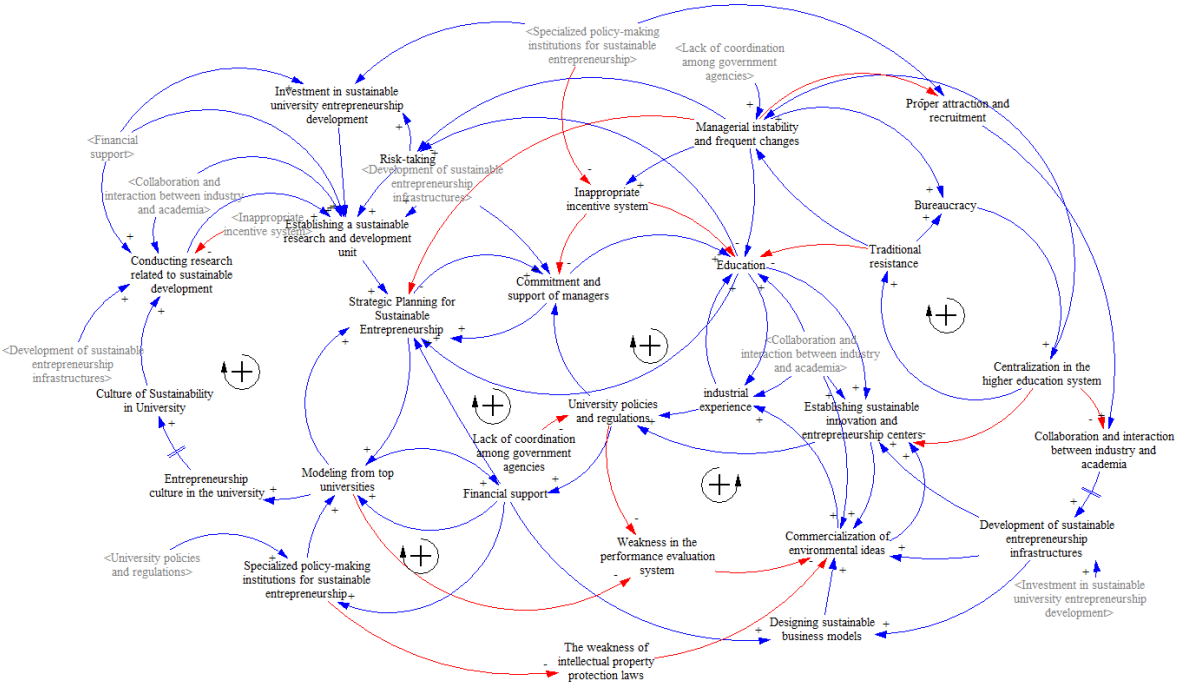

Figure 3. Diagram of the Causal Loop Diagram of sustainable academic entrepreneurship

3.1.3. Stock and flow diagram

This diagram illustrates how the variables within a system interact with one another and can serve as a foundation for developing a quantitative model. In drawing a flow diagram, it is essential to understand two key concepts: stock and flow. In any system, the values of certain variables increase or decrease over time. These are referred to as stock variables. The rate at which these variables increase or decrease is called the flow.

A system's flow diagram can be derived using the literature review, expert opinions, and data collected from time-series sampling. During the development of this diagram, quantitative formulas, qualitative relationships, and numerical functions are utilized.

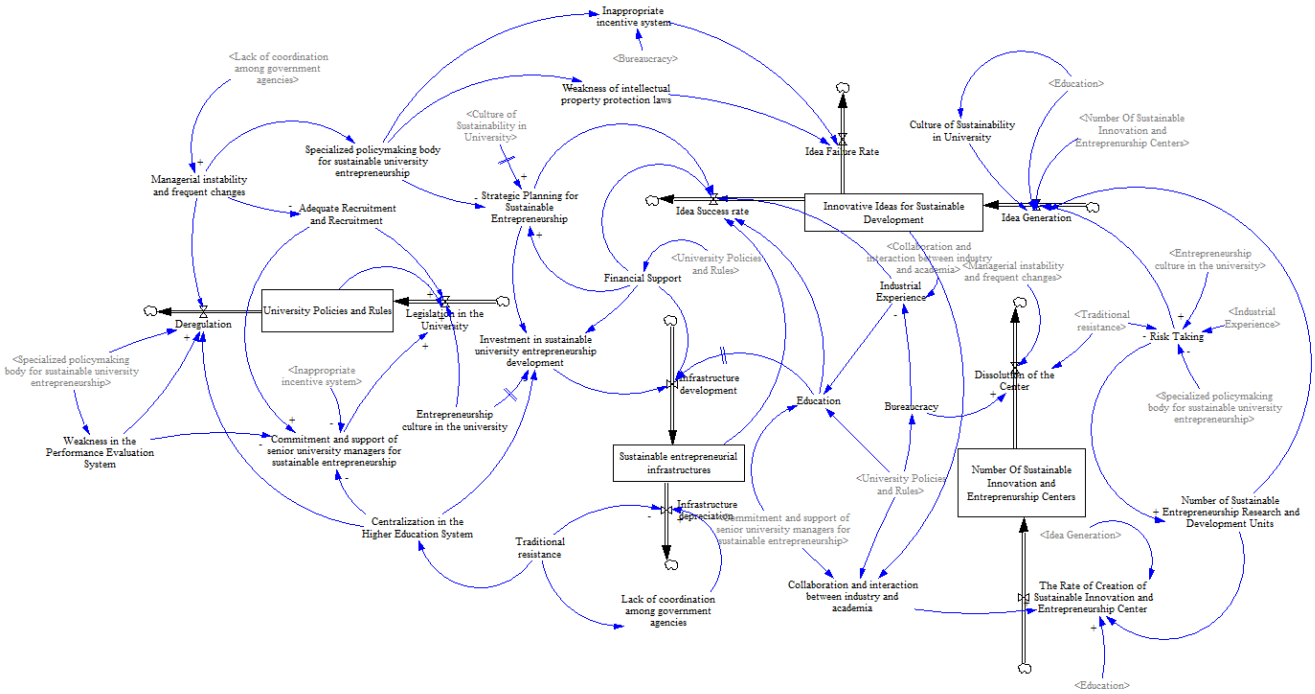

Figure 4. Diagram of the state and flow of sustainable academic entrepreneurship

The stock and flow diagram consists of several important sections. The most significant part of the model is related to the number of innovation and sustainable entrepreneurship centers, which is presented along with the key influencing variables. Another part of the model describes sustainable innovative ideas and the related factors. The most important variable in this regard is idea success rate, which reflects the university's overall performance in achieving sustainable entrepreneurship. Another section of the model addresses variables including managerial instability and frequent changes, weak intellectual property protection regulations, ineffective performance evaluation systems, inappropriate incentive mechanisms, lack of specialized policy-making institutions, bureaucracy, lack of coordination among governmental bodies, and traditional resistance—all of which have a negative impact on sustainable academic entrepreneurship over time. A further section of the model focuses on variables including university laws and policies, commitment and support of senior management, strategic planning, and financial support and investment in the direction of sustainable academic entrepreneurship. These variables have a positive and aligned influence on the development of sustainable academic entrepreneurship.

3.1.4. Model validation

After designing the system dynamics model of the factors influencing the success of sustainable academic entrepreneurship, it is necessary to evaluate its validity prior to simulation. In fact,

validating the flow model is a crucial part of the research process that lends credibility to the research findings. Model validation is essential and significant to ensure the model's acceptability by examining its closeness to real-world conditions (Gray and O'Connor, 2018).To strengthen the credibility of the model, several validation procedures were . performed. These included structural verification, extreme condition tests, and comparison of simulated results with patterns reported in the literature. In addition, iterative feedback from academic experts was incorporated to refine assumptions and parameter values, thereby improving the reliability of the simulation outcomes. To ensure the validity of the model's performance, the following tests were conducted.

a) Model Structure Assessment Test:

This test seeks to answer the question: Is the model structure consistent with the existing knowledge of the system? In response, it should be stated that the identification of variables used in designing the system dynamics model of factors influencing the success of sustainable academic entrepreneurship was based on a comprehensive literature review and relevance to the research topic. In this study, with the assistance of experts and professionals in the field of sustainable academic entrepreneurship, the structure of the model was evaluated, and the structural validity of the model was confirmed.

b) Parameter Assessment Test:

This test addresses the question: Are the parameter values in the model consistent with real-world values? Given that the variables used in the model were derived from previous studies, many of the parameter values were extracted from relevant research, making them aligned with actual values. In cases where the literature did not provide specific parameter values, appropriate estimates were assigned based on expert judgment and consultation.

3.1.5. Model simulation and key findings

System dynamics modeling and simulation help researchers see how complex systems act when different policies or feedback are used. Simulation is not just a technical tool; it is a way to learn more about how real-world systems work. Running simulations based on scenarios lets users check how management practices, policies, and support systems might affect sustainable academic entrepreneurship over time. This matches recent studies that stress the value of simulation for policy design and learning (Elsawah et al., 2020; Lane, 2023). In the end, knowing how the model works lets stakeholders better predict what could happen and find good places to intervene in university entrepreneurial environments. Figure 4 shows the simulation

results made with Vensim, shown as stock-and-flow diagrams. These results show how key factors for sustainable academic entrepreneurship change over time.

One of the key variables in this analysis is “Education”, which began at a very low initial level and gradually followed an upward trend. However, its final value indicates that progress in entrepreneurial education has been slow, and the potential capacities in this area have not yet been fully realized. This weakness can pose a significant barrier to empowering academic human resources in the transition toward an entrepreneurial university. The variable “Managerial Instability and Frequent Changes” started with a relatively high initial value and gradually decreased, albeit with a very slight slope. This pattern reflects a persistently high level of instability throughout the observed period, which could hinder the effective implementation of entrepreneurial policies .The variable “University Policies and Rules” followed a consistent upward trend without significant fluctuations. However, its overall value remained low during the period, indicating structural weakness and the lack of institutionalized supportive policies for sustainable entrepreneurship within universities. Regarding the variable “Commitment and Support of Senior University Management for Sustainable Entrepreneurship”, a declining trend is observed in the early years, followed by a gradual increase in the middle of the period. Nevertheless, the overall variation was limited, and the value remained low, suggesting a lack of strong and consistent managerial will to support entrepreneurial initiatives .The variable “Industrial Experience of Students and Faculty Members” also showed an increasing trend but remained at a low level. This reflects limited university-industry interaction and scarce opportunities for practical experience in real production and economic environments .The variable “Financial Support”, considered one of the most critical factors for entrepreneurial success, experienced a relatively sharp decline over time. This decrease could directly impact universities' ability to support innovation, build necessary infrastructure, and encourage student participation in entrepreneurial activities .The variable “Idea Success rate”, as an indicator of progress toward sustainable academic entrepreneurship, started at a low level but gradually increased with a modest upward slope. Although the pace of growth is not remarkable, it can be interpreted as a sign of a slow yet steady movement toward strengthening innovation infrastructure and building a university-based entrepreneurial ecosystem .Finally, the variable “Number of Sustainable Innovation and Entrepreneurship Centers” was considered as a structural indicator of entrepreneurial success. This variable remained nearly unchanged throughout the period and maintained a generally low level, indicating limited development of institutional support structures in the domain of academic entrepreneurship.

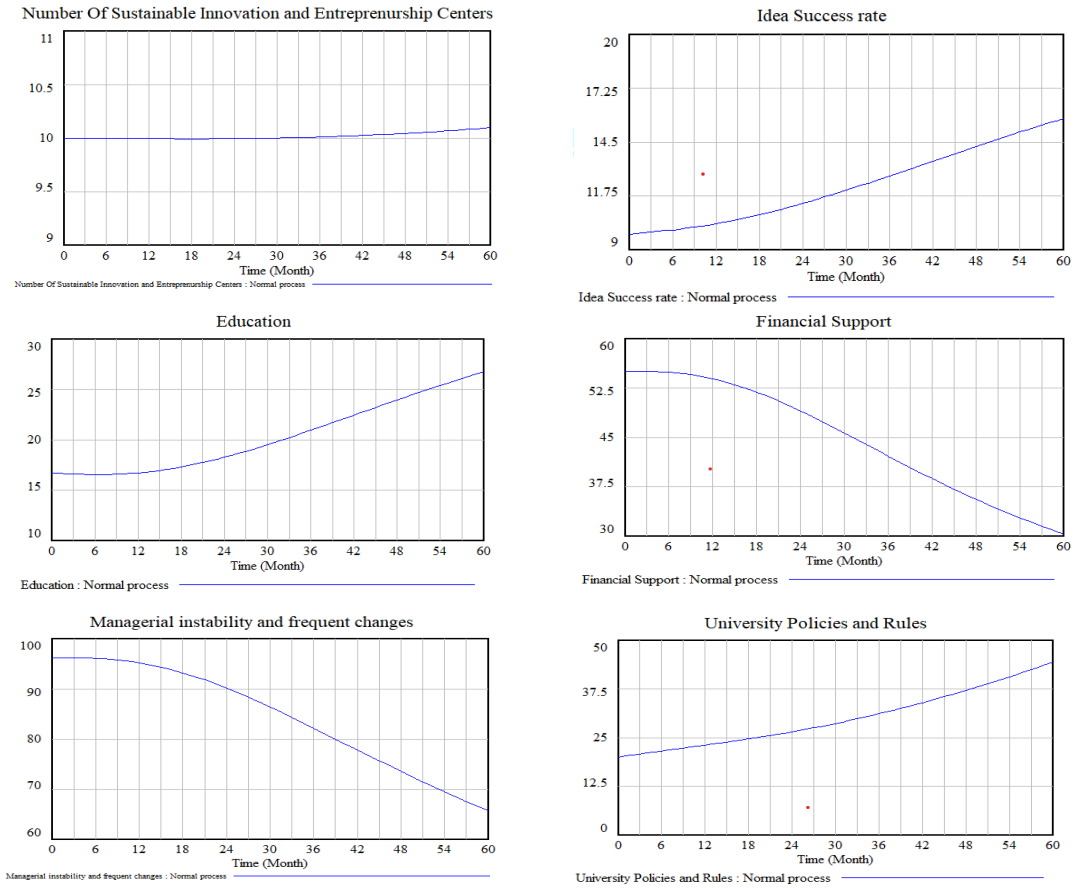

Figure 5. The behavior of the model's key variables during the simulation period

4. Analysis of results (Scenario building and policy evaluation)

One of the most significant capabilities of the system dynamics approach is its ability to incorporate various scenarios and compare their outcomes. Once a valid model with an improved policy structure has been developed, it can be used to design and evaluate alternative future scenarios. At this stage, multiple managerial options can be explored by considering different policy and systemic parameters, and their impacts on the dynamic behavior of the model can be assessed as potential future trajectories. Scenario development involves making different decisions based on the nature of the problem and analyzing their consequences through simulation. The resulting data enable policymakers to evaluate the effectiveness of each strategy and compare its outcomes with one another. In this study, seven policy-oriented scenarios have been developed to analyze and enhance the level of sustainable academic entrepreneurship. In the following sections, each scenario is introduced and discussed in detail.

4.1. Scenario 1: Enhancing the education variable

A significant portion of success in academic entrepreneurship stems from the quality of education provided by universities. In this scenario, the effects of increasing the level of entrepreneurship-related education are examined by analyzing the associated variables. As illustrated in Figure 6, the rate of success for entrepreneurial ideas shows a considerable increase from the beginning of the simulation period. Furthermore, the number of sustainable innovation and entrepreneurship centers begins to rise after a few months, indicating a delayed but positive response to educational improvements (Figure 6).

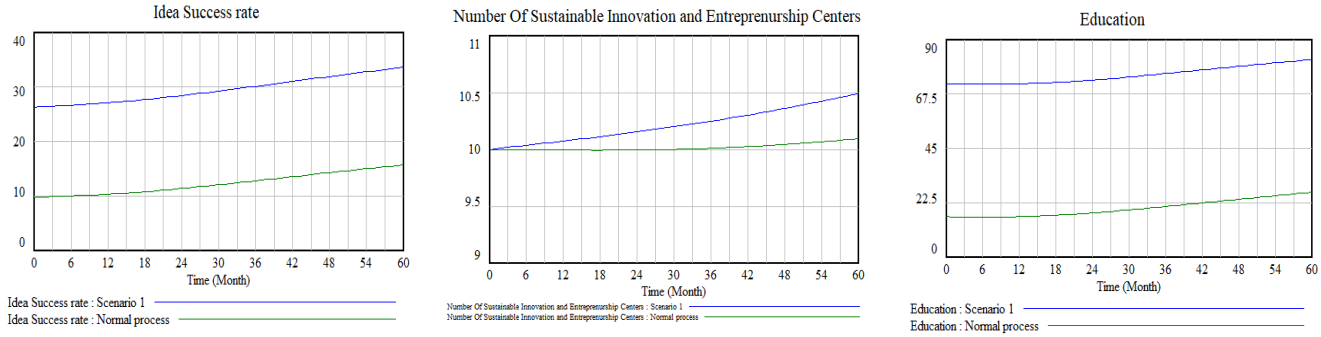

Figure 6. Simulation comparison of key variables under the first scenario and baseline trend

4.2. Scenario 2: Increasing financial support

In this scenario, the level of financial support was enhanced to examine its impact on key variables, including the success rate of entrepreneurial ideas and investment in the development of sustainable academic entrepreneurship. As shown in Figure 7, an increase in financial support leads to a significant rise in both the success rate of entrepreneurial ideas and investment in sustainable academic entrepreneurship (Figure 7).

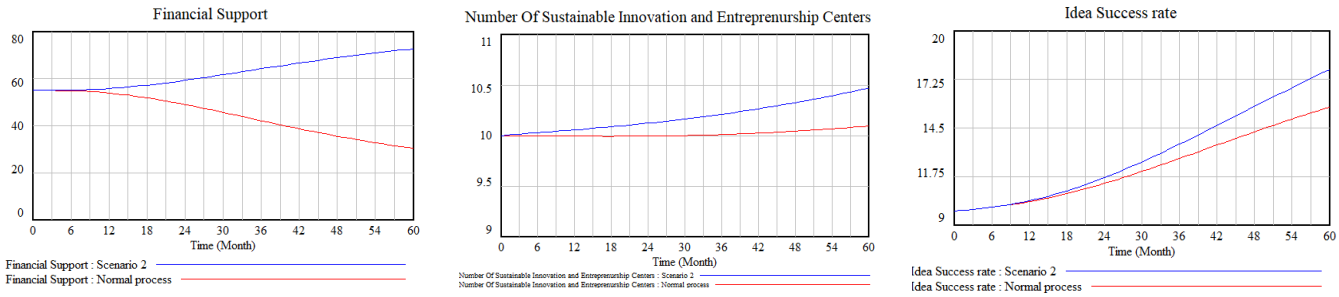

Figure 7. Simulation comparison of key variables under the second scenario and baseline trend

4.3. Scenario 3: Enhancing industrial experience

The third scenario examines the impact of increasing the industrial experience of students and faculty members on the success rate of sustainable entrepreneurial ideas and the establishment

of sustainable innovation and entrepreneurship centers over time. According to the results of this scenario, as industrial experience among students and faculty members increases, the necessary foundation is laid for improving both the success rate of entrepreneurial ideas and the number of sustainable innovation and entrepreneurship centers. Once this foundation is established, it subsequently contributes to an improvement in entrepreneurship education at the university level. These factors collectively play a critical role in advancing and ensuring the success of sustainable academic entrepreneurship (Figure 8).

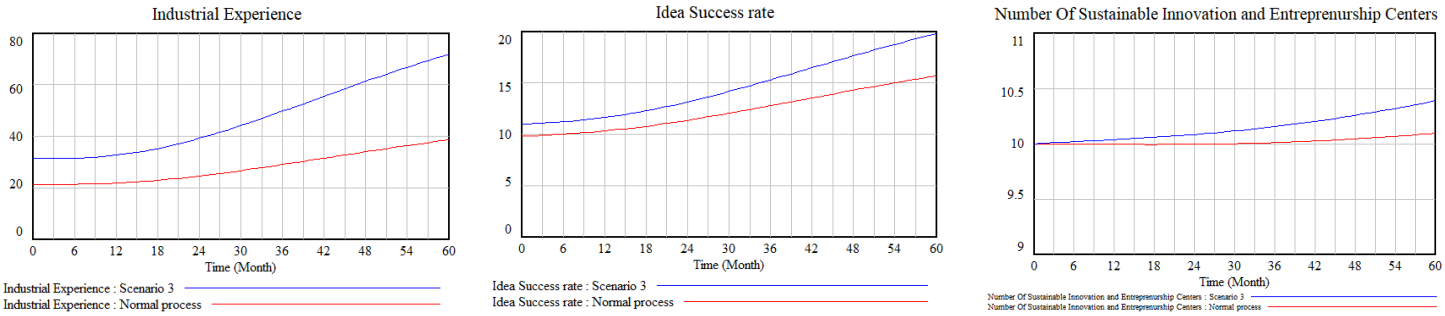

Figure 8. Simulation comparison of key variables under the third scenario and baseline trend

4.4. Scenario 4: Reducing managerial instability and frequent administrative changes

The fourth scenario investigates the impact of managerial instability and frequent administrative changes on the success rate of sustainable entrepreneurial ideas and the establishment rate of sustainable innovation and entrepreneurship centers over time. According to this scenario, reducing managerial instability and minimizing frequent leadership turnover creates the necessary foundation for increasing both the success rate of entrepreneurial ideas and the number of sustainable innovation and entrepreneurship centers. Once such stability is achieved, a more favorable environment emerges for fostering sustainable academic entrepreneurship (Figure 9).

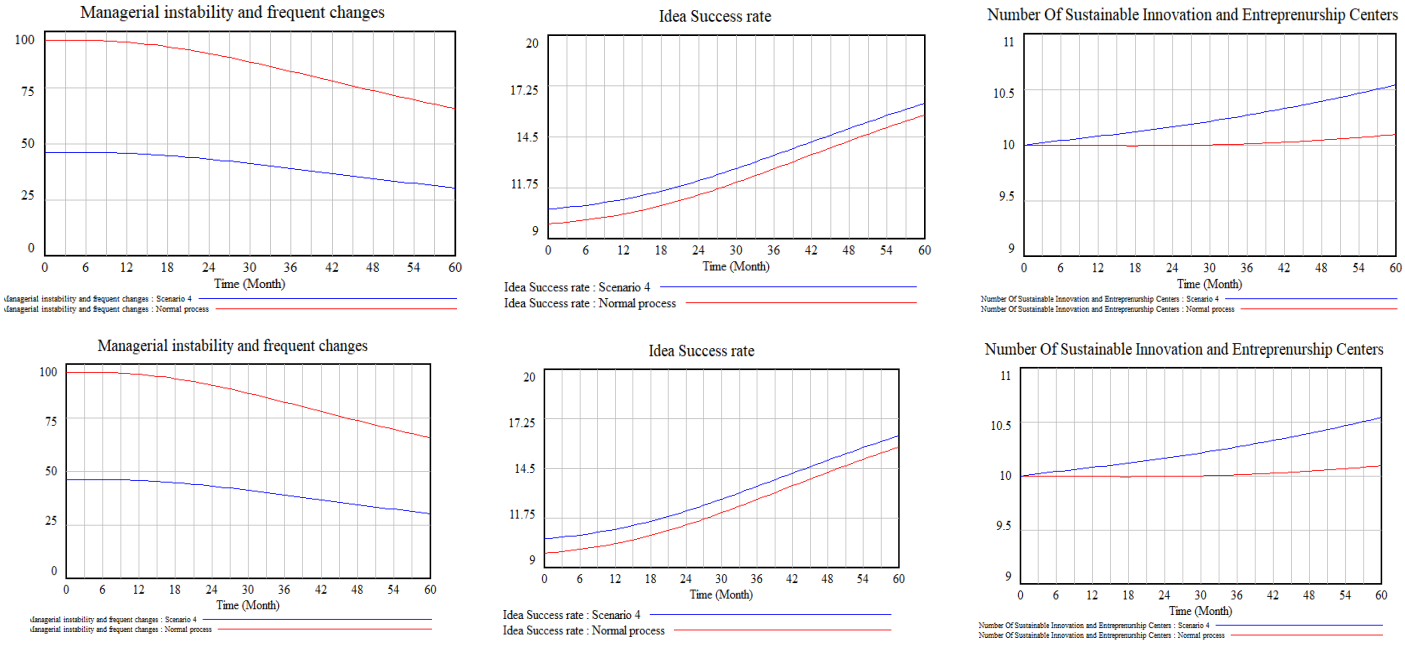

Figure 9. Simulation comparison of key variables in scenario four and normal trend

4.5. Scenario 5: Increasing commitment and support from senior university managers for sustainable entrepreneurship

In the fifth scenario, the model examines the impact of enhancing the commitment and support of senior university managers toward sustainable entrepreneurship on key variables. Figure 10 illustrates the effect of increasing this variable on the success rate of entrepreneurial ideas, education, and the establishment rate of sustainable innovation and entrepreneurship centers. As observed, implementing this scenario results in a significant increase in the number of innovation and entrepreneurship centers as well as in educational efforts. Additionally, the success rate of entrepreneurial ideas shows a similar positive effect, doubling by the final year of the simulation period (Figure 10).

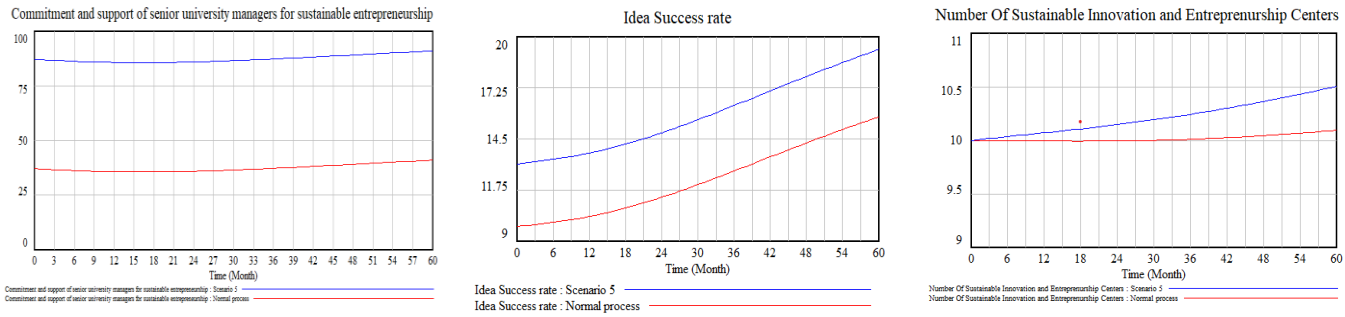

Figure 10. Simulation comparison of key variables in scenario five and normal trend

4.6. Scenario 6: Increasing the variable of policies and regulations

In Scenario 6, the value of the variable policies and regulations was increased, which consequently led to an increase in the variable's idea success rate and the rate of establishment of sustainable innovation and entrepreneurship centers, as shown in Figure 11. The idea success rate exhibited a steep and significant upward trend, while the number of sustainable innovation and entrepreneurship centers also increased considerably.

Figure 11. Simulation comparison of key variables in scenario six and normal trend

4.7. Scenario 7: Simultaneous implementation of scenarios 1–6

The simultaneous implementation of Scenarios 1 through 6 led to a significant increase in both the idea success rate and the number of sustainable innovation and entrepreneurship centers. The upward trend and substantial improvement in these indicators are illustrated in Figure 12.

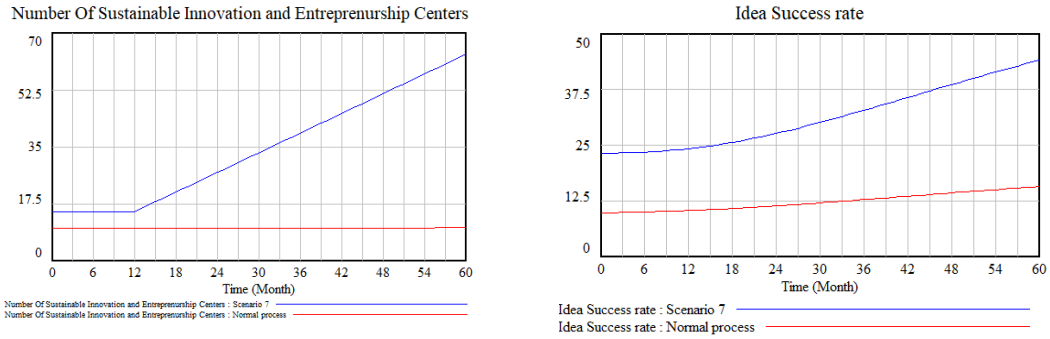

Figure 12. Simulation comparison of key variables in scenario seven and normal trend

5. Conclusion

Sustainable university entrepreneurship is recognized today as a key component of sustainable development within higher education. This study employs system dynamics modeling to analyze the interactive effects of educational, financial, institutional, and managerial interventions on strengthening the entrepreneurial ecosystem within universities. Based on scenario analyses, the following results were obtained:

Scenario 1, focusing on enhancing entrepreneurship education, demonstrated that structured training leads to an immediate increase in idea success rate. However, its impact on the establishment of sustainable institutions exhibited a time lag, indicating that educational interventions require longer-term reinforcement to influence institutional structures. This finding aligns with Etzkowitz (2023), who emphasizes the role of education in enhancing entrepreneurial skills. Scenario 2 regarding financial support revealed that funding has limited short-term effectiveness, and its impact depends on the capacity for institutional absorption and learning. These results are consistent with Sterman (2000) and Guerrero and Marozau, (2023). Scenario 3, examining the increase in industrial experience among members, highlighted its crucial role in strengthening experiential learning and facilitating knowledge transfer into products, reinforcing the importance of industry-academia collaboration (Guerrero and Marozau, 2023). Scenario 4, addressing managerial stability, showed that structural stability and long-term decision-making enhance internal trust and strategic sustainability within the entrepreneurial ecosystem, echoing the findings of Etzkowitz and Zhou (2018). Scenario 5, increasing senior managers' commitment, revealed that leadership support significantly influences all model variables, confirming that committed leadership is fundamental for entrepreneurial transformation (Mousavi et al., 2023; Rasmussen and Wright, 2015). Scenario 6, focusing on policies and regulations, emphasized the pivotal role of clear laws, supportive frameworks, and soft infrastructures in institutionalizing entrepreneurship, consistent with Naderi and Amiri (2021) and Klofsten et al. (2019). Scenario 7, involving the simultaneous implementation of all interventions, showed the highest effectiveness, resulting in systemic and sustainable transformation within universities. This confirms that integrated, multilayered, and synergistic interventions are most effective in developing entrepreneurial ecosystems (Etzkowitz, 2008; Guerrero and Urbano, 2012).

Overall, these findings indicate that sustainable university entrepreneurship cannot be achieved through isolated interventions alone. A systemic, long-term, synergistic, and institutionalized approach is required. Universities that effectively integrate human, structural, and cultural elements are better positioned to contribute actively to national sustainable development.

Limitations and implications: It should be noted that the simulation results are contingent on the selected variables and assumptions, and real-world implementation may vary due to contextual differences. Future research could extend the model by incorporating additional factors such as digital infrastructure, external partnerships, and policy shifts.

Practical recommendations: Universities should prioritize simultaneous interventions in education, finance, management, and policy, ensure leadership commitment, and foster industry-academia collaboration. Policy-makers are advised to support systemic strategies rather than isolated programs, emphasizing long-term and integrated development of entrepreneurial ecosystems.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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