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Artificial Intelligence Capabilities and Sustainable Startup Scalability: The Role of ESG-Oriented Innovation Ecosystems

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Highlights

- AI capabilities can strengthen sustainable startup scalability.
- ESG-oriented ecosystems convert AI use into responsible growth.
- The framework links AI, ecosystems and sustainable business models.
- Five mechanisms and five boundary conditions are proposed.
- The paper advances technology entrepreneurship theory.

Abstract

Artificial intelligence (AI) technology has disrupted how startups sense opportunities, leverage resources, build sustainable business models, and scale up through innovation ecosystems. While significant progress has been made in the study of digital entrepreneurship, entrepreneurial ecosystems, and sustainable entrepreneurship, there is still a lack of theoretical insight into the ways AI capabilities contribute to sustainable startup scalability. This is a conceptual paper that presents an AI-powered sustainable startup scalability framework targeted at the Technovation's community of technological innovation, entrepreneurship, and technology management researchers. The framework draws upon dynamic capabilities theory, the resource-based view, entrepreneurial ecosystems theory, stakeholder theory, and sustainable entrepreneurship literature to posit that AI capabilities foster sustainable startup scalability by being embedded in ESG innovation ecosystems. In addition, the study highlights digital infrastructure readiness, data governance, ecosystem complementarity, absorptive capacity of founders and institutional environment as boundary conditions that affect the scalability and sustainability of venture growth through AI capability. In this respect, the paper advances technological innovation and entrepreneurship literature by shifting its focus from AI adoption within firms and theorizing AI as an ecosystem-embedded capability related to the scalability and sustainability of ventures. Finally, it presents research propositions for scholars as well as implications for entrepreneurs, incubators, accelerators, investors and policymakers that would like to align AI-enabled venture growth with responsible innovation and ESG entrepreneurship.

Keywords: Artificial Intelligence, Sustainable Entrepreneurship, Scalability of Startups, Innovation Ecosystem, Esg, Dynamic Capabilities, Responsible Innovation

Introduction

AI emerges as an inevitable element of any innovation process, entrepreneurship and technology management practice. AI is adopted by startup companies in order to identify the opportunities for innovation, automate experiments, customize customer experience, reduce search cost, accelerate product development, predict changes in the market context, and adjust their business models. At the same time, startups face growing demands to prove that their growth process is not only rapid, but also sustainable, responsible and inclusive. This brings us to a new research question for entrepreneurship and innovation studies – how can capabilities of AI be harnessed by startups in order to ensure their scalable growth without being connected with unsustainable growth rates, poor governance and value extraction.

The suggested topic perfectly fits the scope of Technovation, which concerns itself with technological innovation, entrepreneurship and technology management. It includes discussions on technological innovations and breakthroughs, technology intensive entrepreneurship and firms, science-based enterprises, technology transfer, innovation systems and innovator-as-an-entrepreneur and manager. Therefore, the question of scalability and use of the capabilities of AI would be very relevant to the scope of Technovation. The proposed topic can also cover questions of economic and social innovation, as sustainable startups might be interested.

Historically, a scalable startup is described as having rapid revenue growth, using repeatable methods, relying on digital technologies, venture capital, and growth in the marketplace that has declining marginal costs. But in today's environment, startups have to do more than grow rapidly; they also need to prove that they are ESG responsible towards investors, customers, regulators, and workers. Climate tech, circular firms, health techs, ethical fin-tech, ed-tech, and green mobility startups all need to grow not only at a rapid pace but also responsibly and ethically.

This challenge becomes even more intricate with the advent of AI. In certain situations, there is a possibility that AI would enable the scaling of startups even further by helping with faster learning, cost reduction of experimentation and prediction, automation, and increase in ecosystem intelligence. It will help with understanding customers' needs better, resource optimization, calculating the trade-offs between sustainability, and connecting with other components of the ecosystem. At the same time, AI poses various risks, such as amplifying biases, increasing energy expenditure, loss of accountability, growth through surveillance, lack of human control, and greenwashing.

Past research gives us a number of relevant insights regarding different aspects of the challenge. Digital entrepreneurship research highlights the importance of digital technology for opportunity emergence, digital artifacts, dynamics of venture development, and new business models [1-7]. Entrepreneurial ecosystems studies highlight the significance of network relationships, institutions, financial instruments, organizational culture, supporting organizations, platforms, and complementarity of

venture development [8-14]. Within the domain of sustainable entrepreneurship research, the effect of ventures is viewed in terms of addressing both environmental and social challenges and generating economic benefits, including through business model innovations and capabilities of business models [15-21]. Research in the field of AI and sustainability touches upon the potential of artificial intelligence technology for the SDGs, efficient resource utilization, sustainable decision-making processes, digital sustainability, as well as the adverse effects of AI technology on the environment and society [22-25]. Contemporary studies in the sphere of AI entrepreneurship indicate the usefulness of AI technology in making decisions, innovating, and scaling up of ventures [4,26,27]. In spite of these developments, however, a number of gaps within the existing literature in three spheres persist. First of all, AI technology itself appears as a digital tool utilized at the firm level rather than an ecological one. This implies that stakeholders' influence on the creation of value by startups through AI technology may go unexamined. Secondly, the concept of scalability of startups in itself can be assessed regardless of sustainable activities.

The goal of this study is to close these gaps through a theoretical framework regarding how AI capabilities foster sustainable startup scalability in ESG innovation ecosystems. The research question in this paper is formulated as follows: How do capabilities of artificial intelligence foster sustainable startup scalability within ESG innovation ecosystems? To answer the research question, this study has used several theories, which include dynamic capabilities theory, resource-based theory, entrepreneurial ecosystem theory, stakeholder theory, and sustainable entrepreneurship research. According to the authors, AI capabilities facilitate sustainable startup scalability through five mechanisms, including AI-based opportunity sensing, sustainable business model experimentation, ecosystem resources orchestration, ESG intelligence and accountability, and responsible scaling governance.

This study offers four contributions to the existing literature on sustainable entrepreneurship and technology startups. Firstly, this research contributes to technology entrepreneurship studies by seeing AI capability as ecosystem embedded scaling capability instead of being considered only as digital capability. Secondly, this research contributes to sustainable entrepreneurship literature by linking venture scalability with ESG innovation ecosystems. Thirdly, it contributes to the entrepreneurial ecosystem theory by showing the role of ecosystem stakeholders in shaping the sustainability implications of AI-enabled scaling capabilities. Lastly, it formulates hypotheses for further research.

Conceptual Background

AI capabilities in technology entrepreneurship

The AI capabilities of the company reflect its ability to identify and take advantage of opportunities that are linked to acquiring, building, combining and leveraging AI resources, which include such elements as the data infrastructure, machine learning algorithms, analytical skills, AI decision support systems, experiments, and AI governance processes. First, AI is helpful for technological startups because of the specific nature of the venture business and its inherent conditions – uncertainty, resource constraints and time limitations. With the help of AI, startups can reduce the

cost of search activities, conduct iterations, and process different signals from markets, technologies, and ecosystems.

However, AI capabilities should not be equated exclusively to technical assets. According to the resource-based view, the latter will only bring benefits for firms when complemented with other kinds of resources, including data, routines, skills, leadership and organization [14]. Although it is possible for startups to purchase generic AI technologies, they still have to implement those within their particular value propositions and business models. From this point, AI capabilities can be considered learning from data, business model adaptation, and responsible application of technology.

This is yet another approach that can help explain the phenomenon – dynamic capability theory. An entrepreneur must be able to sense, seize and reconfigure his/her capabilities when faced with uncertainties [6]. The application of AI might facilitate sensing via conducting market research and analysis, predicting demand, identifying sustainability challenges, and finding opportunities for innovation. Seizing may be facilitated for startups with AI by quickly testing out prototypes, conducting automated customer discovery processes, and distributing resources. Artificial intelligence may help in reconfiguration processes as well. This will be extremely useful for digital startups because scalable growth involves constant reconfigurations, not one-time opportunities.

Scalability of startups outside rapid growth

Scaling is an aspect that relates to the capability of a venture to expand beyond the available resources without bearing substantial costs, added levels of complication, and management difficulties. Digital ventures are considered highly scalable since they can scale rapidly owing to the use of software, platforms, and services. However, scalability concerns not only economics and technology but also issues related to organizations, institutions, and ethics. Therefore, rapid growth for a startup may lead to negative social consequences, poor corporate governance, and environmental harm. Such a process can be impressive in commercial terms.

That is, sustainable startup scalability means that a startup manages to grow in its presence, revenue, impact, organizational capacity, all while taking into account its effect on the environment, societal approval, and corporate governance. Sustainable scalability is a more comprehensive concept than conventional notions of scalability. Sustainability here refers not only to growth but also to replication of the business model, flexibility of the venture, legitimacy of the growth approach, responsibility in using technologies, and the possibility of creating positive environmental or social impacts.

ESG-oriented innovation ecosystems

This implies that sustainable scalability in startups means the capacity to scale beyond the presence, profitability, social impact, and ability of the startup, yet be mindful of its impact on the environment and socially as well as the good corporate governance practices. Sustainable scalability is different from traditional approaches to scalability. While growth is involved in sustainable scalability, it also incorporates replication,

adaptability, legitimacy, responsibility, and impact on society or the environment of the business venture.

ESG-oriented innovation ecosystems constitute a special type of entrepreneurial ecosystems in which sustainability-related needs, abilities, and accountability mechanisms influence ventures. Examples of such ecosystems include climate investors, impact accelerators, ESG reporting services, sustainability coaches, green tech proving grounds, public procurement, regulatory sandboxes, academic organizations, corporations, and impact-oriented governments programs. Such ecosystems help startups leverage their AI capabilities to create a sustainable business model.

In light of the fact that ventures which rely on artificial intelligence technology can expand in entirely different directions, it becomes crucial to emphasize that the operations of AI-related ventures should take place within ecosystems that favor sustainable development. The venture in question can use the technology it possesses to increase engagement among users, reduce costs associated with human labor, or build platforms that are extractive. Alternatively, ventures can utilize their capacity to achieve environmental and social sustainability objectives.

Sustainable entrepreneurship and responsible innovation

Sustainable entrepreneurship refers to entrepreneurial activities that address societal and ecological issues, thus making value at the same time [15-19]. Indeed, literature suggests that there are multiple reasons why entrepreneurship is possible: market failure, ecology degradation, social exclusion, institutional voids. Responsible innovation is related to anticipation, inclusion, reflexivity, and responsiveness when developing new technologies. Based on the above literature, an AI start-up should be assessed through the lenses of speed, valuation, users. In addition to these factors, start-ups should also be evaluated regarding their ability to anticipate the consequences, involve different stakeholders, think about trade-offs, and respond to social challenges.

The above perspective is important in the context of the ongoing discussion. Yes, AI can help develop sustainable entrepreneurship, but only by treating the latter as responsible innovation. In particular, start-ups need to think about the issue of algorithmic justice, data privacy, impact on the environment, relationships with labour, and the matter of accessibility, governance. Thus, the sustainable scalability of a start-up should also include the AI growth potential and responsible scalability governance.

Literature Review and Research Gaps

Digital entrepreneurship and venture creation with the help of AI

Literature on digital entrepreneurship shows that digitization implies transformations in the very nature of entrepreneurial opportunities, ventures and their scalability [1,2]. Digital artifacts are flexible, reconfigurable, and easy to distribute, thus enabling fast experimentation by startups and cross-border selling of products. In turn, the use of AI technology in entrepreneurship leads to even more flexibility since it provides predictability, automation and adaptability of learning processes in the course of entrepreneurship. For example, AI may be utilized to create business opportunities,

create a product, analyze the customer segment, estimate risks, and interact with investors.

As it follows from recent publications, AI is one of the critical factors of entrepreneurship and its evolution. Thus, Chalmers et al. argue that AI influences venture creation amid the fourth industrial revolution as it affects cognition, decision-making and management of resources [4]. Al-Mamary proves that AI features related to decision-making, innovation, risk management and competitive advantages have a great impact on venture outcomes [26]. Moro-Visconti et al. believe that AI scalability can influence company value and sustainability as it will be associated with higher revenues and cost savings [27]. Nonetheless, none of the papers discussed above touch upon how ESG and ecosystems can be preserved.

Venture ecosystems and venture scaling

The ecosystem theory in entrepreneurship literature describes venture scaling based on the quality of the external systems that provide such scaling support. As Stam claims, ecosystems are defined by systemic and framework factors enabling productive entrepreneurship [8]. Alternatively, Spigel highlights organizational relationships in his definition of ecosystems that include cultural, social and material dimensions [9]. Consistent with this perspective, Wurth, Stam & Spigel call for research into the entrepreneurial ecosystem that goes beyond simple descriptive accounts of ecosystems' components and focuses on their mechanisms of functioning [11]. Relatedly, existing ecosystem literature demonstrates that digital capabilities, ecosystem architecture, and complementarities influence value creation and scaling [3,12-14].

When it comes to startup operations, ecosystems become crucial to their scaling up processes. Scaling requires access to capital, skills, customers, legitimacy, infrastructure and knowledge. In addition, when dealing with AI-powered startups, data resources, computational power, moral guidance, clarity of regulations and knowledge also become critical for success. Importantly, startups have no access to these resources individually. For this reason, the scalability of AI-powered ventures is inherently ecosystemic.

Sustainable Entrepreneurship and ESG Growth Orientation

Researches in sustainable entrepreneurship claim that enterprises may solve issues connected with both environment and society, and create economic value simultaneously [15-19]. According to Hall, Daneke, and Lenox, entrepreneurship might have positive impact on the sustainable development, while having a few negative sides as well [15]. Hockerts and Wustenhagen make a distinction between newcomers (green entrepreneurs) and already established companies that may involve in the sustainability transition through entrepreneurship [16]. Schaltegger and Wagner highlight the importance of sustainable entrepreneurship and innovation [17]. The principles of sustainable business models, such as energy and material efficiency, resource circulation, renewability, and product service systems, have been developed by Bocken et al. [18]. Researches in business model innovation provide information about design of sustainable value creation in scalable ventures [19-21].

It provides the much-needed framework in terms of startup scalability focused on ESG criteria. However, in general, it fails to account for the capabilities of AI and its operations within digital ecosystem contexts. The explanation lies in the fact that most of the theories on sustainable entrepreneurship emerged before the advent of the latest AI systems, which provided businesses with chances to build scalable AI-based platforms. In other words, there is a clear disconnection between the ideas of sustainable entrepreneurship and AI-driven opportunities.

Artificial Intelligence and Sustainability: the Digital Sustainability Paradox

The research on "AI for sustainability" indicates how artificial intelligence could contribute to sectors like environment monitoring, resource management, climate prediction, sustainable investments, health, education, and other Sustainable Development Goals (SDGs). In particular, Nishant, Kennedy and Corbett outline a research agenda for AI and sustainability, mentioning both its potential benefits and challenges [23]. At the same time, Vinuesa et al. conclude that although AI could help achieve many SDGs, at the same time, it could also become an obstacle in their accomplishment owing to its improper governance [22]. Consequently, Di Vaio et al. and George, Merrill and Schillebeeckx discuss issues of digital sustainability, AI-based business models and digital entrepreneurship for sustainable development and climate change mitigation [24,25].

The digital sustainability paradox underpins the suggested approach. Indeed, AI technologies could assist with solving problems related to sustainability; nevertheless, AI could exacerbate such sustainability problems because of energy consumption, data exploitation, algorithmic bias, and platform concentration. From an entrepreneur's perspective, this question is especially acute because there is often a need for scaling and raising funds rapidly. The ESG ecosystem, failing to offer adequate support to the startups, will not leave them much choice but to pursue rapid scaling instead of sustainable development. Therefore, scaling AI combined with ESG intelligence should be the standard going forward.

Gaps addressed by this paper

There are four areas that could be identified as potential research gaps in the literature. The first one is that research on AI-based entrepreneurship overlooked the question of embedding AI capabilities in ESG innovation ecosystems. Second, there was not enough research done concerning the role of AI as scaling capabilities at the ecosystem level. The third gap is that research related to sustainable entrepreneurship did not include experiments, data intelligence, and responsible AI governance among the theoretical foundations. Finally, scalable startups were considered mainly with regards to efficiency but neglected their other sides.

It may be useful not only for further empirical research but also will help entrepreneurs, accelerators, investors, and policymakers.

Theoretical Framework

Resource-Based View

A resource-based approach offers an understanding of the strategic significance of AI capabilities for startups [28]. While the availability of AI technologies may not be an

issue anymore, the use of these technologies differs a lot. The value created by startups arises from integrating AI technologies together with proprietary data, expertise, insights of startup founders, learning, customer insights, and ecosystem connectivity. This approach can be hard to copy because of its path dependence and embeddedness.

In order to achieve scalable outcomes, it is clear from the resource-based perspective that building AI capabilities should focus on creating value rather than automating everything. Thanks to AI, startups will benefit from efficient resource allocation, customer learning, innovative products, and ESG measurement. Nevertheless, the listed advantages can be achieved in the presence of complementarities.

Dynamic Capabilities Theory

The dynamic capabilities approach suggests that startups cope with uncertainties [21,29]. The application of AI might improve dynamic capabilities through enhanced sensing, seizing, and reconfiguring processes. Sensing can help startups become aware of possible opportunities in the market, sustainability-related issues, changes in regulation and stakeholders' expectations. Seizing is the set of activities that enables experimentation, priorities management, and resources allocation. Reconfiguring implies modifying the startup's business model, processes, and eco-system interactions.

This theory is particularly relevant to scalable startups due to the non-linear nature of the scaling process. Indeed, scaling requires constant efforts on achieving product-market fit, improving operations, getting financing, reaching new markets, and gaining legitimacy. Speedier learning and reduced uncertainties owing to AI will definitely help achieve better scaling results. However, the challenge is to make sure that dynamic capabilities bring sustainable outcomes. Otherwise, if the entrepreneurial ecosystem ignores ESG rules, scaling itself becomes an unsustainable practice regardless of AI support.

Entrepreneurial Eco-System Theory

In terms of entrepreneurial eco-systems theory, the scalability of startups is not something that can be understood in a standalone perspective. The role of the ecosystem becomes particularly important when the subject of discussion is resources, legitimacy, knowledge, and institutions [8-14]. AI-focused startups will need the support of ecosystem participants, who will provide them with data, computing power, finance, mentoring, pilot projects, regulations, and sustainability measures.

This is why this paper approaches AI capability as both a firm-based and an ecosystem-oriented phenomenon. Indeed, while the startup will have AI capabilities on its own, they will possess the capacity for scalability because of complementary elements that exist within the ecosystem. It may come in the form of investment from investors for scaling purposes, market access from accelerators, expertise provided by universities, sandbox tests from regulators, and measurement standards from ESG intermediaries.

Stakeholder theory
The stakeholder theory states that firms must create value for several stakeholders [30,31]. For startups using AI, these stakeholders include customers, employees, communities where they operate, suppliers, investors, government bodies, and even the environment. Thus, scalable startups should think about how they affect stakeholders and develop models that help achieve legitimacy. AI will assist by analyzing feedback, evaluating social risks, and managing ESG practices. At the same time, AI can put stakeholders at risk due to its violations of privacy, discrimination, and opaque decision-making.

Responsible innovation and sustainable business models
Responsible innovation involves four areas of interest: anticipation, inclusion, reflexivity, and responsiveness. Research on sustainable business models encompasses issues related to the creation, delivery, and realization of value by businesses, while also ensuring a minimal environmental impact and greater social value [18-21]. Considering both approaches together entails evaluating the scalability of AI-powered startups using their business model.

Conceptual Theory-Building Approach
As a result, in connection with the problem nature under consideration, a theory-building research is conducted within the present paper, which means that existing theories and research results are used to create an analytical framework aimed at studying how AI helps achieve sustainable startup scalability by developing innovation ecosystems aligned with ESG factors.

The research process includes four important steps. First of all, constructs from the spheres of technology entrepreneurship, entrepreneurial ecosystems and sustainable entrepreneurship are highlighted. They include AI capability, startup scalability, ESG-oriented innovation ecosystems and sustainable business model experimentation. Next, lenses to interpret these constructs are identified, including resource-based view, dynamic capabilities, entrepreneurial ecosystems theory, stakeholder theory and responsible innovation. Then, mechanisms explaining relationships between constructs described earlier, especially between AI capability and sustainable startup scalability are defined.

The unit of analysis is the startup that operates within the innovation ecosystem. It is essential to understand this point since the startup is autonomous and interactive at the same time. The autonomous characteristic refers to the use of the startup's abilities to learn, experiment, and coordinate based on artificial intelligence, whereas the interactive element refers to how much impact the innovation ecosystem participants have on the available resources, legitimacy, and accountability of the startup.

This research framework is useful not only for developed countries but also for developing ones in particular when the innovation ecosystem fostering sustainable entrepreneurship is formed, the startup faces resource shortages, and the requirement to meet ESG standards emerges.

AI-Enabled Sustainable Startup Scalability Framework

The author proposes an AI-Enabled Sustainable Startup Scalability Framework in this paper, in which it is stated that artificial intelligence assists in developing sustainable startup scalability through five stages, including opportunity sensing using AI, sustainable experimentation in business model, resources orchestration within ecosystems, intelligence about ESGs, and scaling management. The above mentioned five stages depend on five boundary conditions, including digital readiness, data governance, ecosystem complementarity, absorptive capacity of entrepreneurs, and institutional support.

The connection between stages and boundary conditions is explained in Table 1.

Mechanism	**Main AI function**	**Ecosystem role**	**Scalability contribution**
AI-enabled opportunity sensing	Detect market, technology and sustainability signals	Provides data, policy signals and mission challenges	Identifies scalable sustainability opportunities
Sustainable business model experimentation	Models alternatives and tests assumptions	Offers pilots, mentors and impact standards	Refines repeatable and responsible growth models
Ecosystem resource orchestration	Maps and coordinates partners, investors and resources	Supplies complementary assets and legitimacy	Expands resource access for scaling
ESG intelligence and accountability	Measures and monitors ESG outcomes	Provides reporting norms and stakeholder expectations	Maintains legitimacy during growth
Responsible scaling governance	Supports oversight, risk detection and ethical controls	Creates standards and responsible innovation norms	Reduces governance risks of rapid growth

Table 1. framework with links to each mechanism to its theoretical basis and scaling implication.

Opportunity Sensing through AI

Opportunity sensing via AI means applying AI to sense the presence of market needs, new technologies, sustainability challenges, and many other kinds of problems confronted by stakeholders. In general, startups exist in ambiguity and rely on weak signals received from their clients, competitors, policymakers, and ecosystem. Opportunity sensing using AI makes it possible for a startup to make use of various tools, including but not limited to: analysis of search trends; customer data analysis; environmental signal analysis; patent analysis; policy analysis; social network analysis; operational data analysis. As a consequence, opportunity sensing using AI helps startups see opportunities which might turn out to be commercially and/or sustainably valuable.

To illustrate, a climate-tech firm can use AI to detect energy inefficiencies in different buildings, a health-tech company can use AI to reveal neglected segments of society, and a circular economy startup can apply AI to spot waste flows available for recycling. The common thing in all these cases is that each firm can gain from using AI to sense challenges which will later become opportunities. Opportunity sensing using AI relates to dynamic capabilities because opportunity sensing is the initial step of dynamic adaptation [21,29]. In other words, the sustainability of opportunity sensing powered by AI can be ensured through integrating ESG factors in the search activities. If not so, the adoption of AI technology would just mean an acceleration of unsustainable development. The following are some aspects of the ESG ecosystem which can influence the process of sensing opportunities via AI through ESG datasets, mission, impact investors, regulations, and stakeholders.

Experimentation with sustainable business models

Experimentation with sustainable business models refers to AI-powered efforts aimed at testing out growth-oriented business models based on ESG outcomes. Companies often conduct experiments as a way of validating their hypotheses. Using AI technologies, startups can enhance experimentation activities by segmenting customers, conducting scenario analysis, prototyping, carrying out A/B tests, building simulations, and predicting impacts.

This process is essential for the purpose of sustainable startups since various targets are set by businesses, such as value creation for customers, profitability, attracting investment, and meeting social and environmental goals. In this regard, artificial intelligence can help founders in balancing between costs, carbon footprint, reach of customers, inclusivity, and feasibility. For instance, a logistics company can experiment with various routes not only from the perspective of cost efficiency and time optimization. Business model experimentation for sustainability is related to the capability for artificial intelligence in that companies that are able to experiment quicker will arrive at a replicable business model more quickly. Nevertheless, experiments have to take place in an ethical manner, considering that experiments pose a risk to the users that come into contact with opaque or biased processes.

Ecosystem Resource Orchestration

The notion of ecosystem resource orchestration is related to how well a startup uses artificial intelligence technology to access and coordinate resources within the innovation ecosystem. Scaling requires more than just the internal capability of the startup. Financing, partners, pilot customers, technical expertise, data access, talent, regulatory advice, and legitimacy are all required. Artificial intelligence might help with ecosystem resource orchestration by providing capabilities like network mapping, fund sourcing, technology-to-market matching, supplier evaluation and collaboration coordination.

However, ESG intelligence must be differentiated from ESG signalling. AI might generate stunning dashboards without any improvements in sustainability. Thus, accountability becomes crucial. AI-driven ESG system should be open, auditable and associated with decisions. For instance, if the startup receives an indication that the design of the product entails increasing its energy use, it will use this information for

improving its design. In case AI finds that the model is based on biased criteria, the startup will correct its model.

This approach connects sustainable entrepreneurship with stakeholder theory. The reason behind the link between them is that ESG intelligence makes it easier to track the effects of scaling on stakeholders and on the environment. This way, startups can demonstrate their legitimacy and ensure that scaling takes place in a responsible manner. At the same time, investors and accelerators can evaluate whether scaling happens responsibly.

Responsible scaling governance

Responsible scaling governance stands for those institutional mechanisms which guarantee that AI-driven growth of a startup occurs ethically, sustainably and effectively. Startups are known to focus primarily on speed, experimenting and building market traction. These characteristics help the startup to scale, but they might bring certain governance risks. These risks are further Orchestration of resources in an ecosystem is particularly critical for sustainable ventures as they need specific types of ESG growth. For example, green-tech startups may need laboratories, regulatory assistance, and adoption by corporations. Similarly, social-impact businesses will have a need for community partners and government legitimacy. AI can facilitate these connections and orchestrations, but the effectiveness of the complementarities of an ecosystem will ultimately determine the value of such actions.

ESG intelligence and accountability

Intelligence and accountability regarding ESG concerns involve systems that leverage AI in gathering, analyzing, and sharing information on environmental, social, and governance activities. In today's business world, more and more startups need to prove their impact to stakeholders including investors, clients, government authorities, and other ecosystem partners. Using AI technology, startups can measure and track their ESG metrics by gathering and analyzing data, monitoring carbon emissions, assessing social risks, analyzing stakeholder opinions, and creating dashboards to visualize impacts.

This mechanism extends entrepreneurship ecosystem theory by proposing that artificial intelligence technology can increase the effectiveness and intelligence of ecosystem embedding. The startup can utilize artificial intelligence to find out which parties are important for its scaling and sustainable development goals. The same holds true for accelerators and incubators which can use artificial intelligence to connect startups to potential mentors, financiers.

This aspect becomes important since scaling by means of artificial intelligence without proper governance could pose legitimacy threats to a startup. While a business could scale up quickly, later problems such as a lack of trust, regulation and environmental issues would become a problem. This can be prevented with proper governance which would create more sustainable scaling opportunities. ESG-focused ecosystems could contribute to the process of governance via standards, investor due diligence, accelerator programs, regulatory advice and responsible innovation.

Boundary conditions

There are five boundary conditions affecting the power of this framework. Firstly, readiness of digital infrastructure will determine the extent to which the deployment of artificial intelligence will prove successful. If a startup lacks efficient data management systems, cloud computing capacity and technical personnel, artificial intelligence capabilities become compromised. Secondly, data governance will determine whether AI is reliable, ethical and accountable. Inefficient data management will affect the processes of scalability and sustainability positively. Thirdly, complementarities in an ecosystem will allow startups to acquire necessary resources. Fourthly, founder absorptive capacity will influence whether they can learn from the new knowledge. Finally, institutional support will facilitate responsible innovation.

These boundary conditions can be critical in emerging economies where infrastructure, data, skills, and support institutions may not be uniform. They also justify the potential different outcomes resulting from AI capabilities. A start-up that is well-endowed with AI talent but lacks ecosystem support will likely have challenges scaling sustainably. On the other hand, a start-up embedded in a supportive ESG ecosystem will turn its relatively modest AI capabilities into sustainability outcomes.

Conceptual Propositions

The proposed framework gives rise to ten propositions for future empirical testing.

Proposition 1: AI-based opportunity sensing will positively impact sustainable startup scalability through improved opportunities' identification.

AI enables new ventures to analyze intricate data and identify signals in markets, technologies, and sustainability issues. In case ESG considerations inform the opportunity identification process, AI-sensing may help uncover opportunities that offer growth alongside environmental or social benefits.

Proposition 2: Sustainable business model experimentation acts as a mediator between AI capabilities and sustainable scaling.

Scaling value through AI capabilities occurs when startups experiment with different business models. The mediation function of sustainable business model experimentation consists of converting AI-based learning into scalable, repeatable, and ESG-driven value creation.

Proposition 3: Ecosystem resource orchestration acts as a mediator between AI capabilities and startup scaling.

Scalability of a startup results from the distribution of necessary resources in ecosystems. Through AI, startups can optimize for resource detection and orchestration by tapping into different ecosystems and identifying various stakeholders such as investors, mentors, and sustainability actors.

Proposition 4: ESG intelligence and accountability act as a mediator between AI capabilities and sustainable legitimacy.

Using AI technology for ESG monitoring will enhance the level of legitimacy that startups exhibit. Accountability and transparency regarding ESG issues are critical for legitimacy creation in a startup.

Proposition 5: The implementation of responsible scaling governance enhances the connection between AI capabilities and sustainable start-up scalability.
The growth driven by AI technology may carry ethical and ecological risks. The use of responsible scaling governance helps to ensure that growth driven by AI technology is trusted and sustainable. This leads to the increase in sustainability value provided by AI capabilities.

Proposition 6: Digital infrastructure preparedness positively moderates the connection between AI capabilities and sustainable start-up scalability.
Start-ups need to have proper data management systems and computing infrastructure to use AI technology efficiently. High levels of digital infrastructure preparedness help to strengthen the link between AI capabilities and scalable growth.

Proposition 7: Data governance positively moderates the connection between AI capabilities and ESG intelligence.
The development of ESG intelligence driven by AI technology needs proper data governance because otherwise, misleading results can be obtained.

Proposition 8: Ecosystem complementarities positively moderate the relationship between AI capability and ecosystem resource orchestration.
AI identifies resources; however, scaling is dependent on whether there are complementary entities within the ecosystem and accessibility. Strong complementarities will raise the value of the AI-driven ecosystem orchestration process.

Proposition 9: Founder absorptive capacity positively moderates the relationship between AI capability and sustainable business model experimentation.
The ability of a founder to absorb knowledge about AI and sustainability practices plays an important role in the creation of business models that are able to scale sustainably.

Proposition 10: Institutional support positively moderates the relationship between ESG-oriented innovation ecosystems and sustainable startup scalability.
Public policy, regulation, standards, and initiatives will determine whether the innovation ecosystem rewards responsible innovation by startups.

Discussion

The presented framework proposes a core argument about what makes artificial intelligence capabilities contribute to sustainable startup scalability: such contributions are possible only if AI capabilities are embedded into ESG innovation ecosystems. The shift from considering the issue of adoption of AI tools to thinking about the strategy

of building AI-enabled ESG innovation ecosystems is an important theoretical move here.

There are several consequences of this framework for startup growth theory. The existing literature on startup scaling focuses on disruptive growth, fast expansion, and valuation, etc. Such a focus creates incentives for entrepreneurs to scale up at any cost. As a result, there might emerge unstable ventures and social unrest as a consequence of irresponsible growth. AI capabilities can help startups scale more efficiently and effectively but they can be used irresponsibly as well. Hence, sustainable startup scalability presupposes balancing scaling capabilities and appropriate governance practices.

Additionally, the framework changes the conception of entrepreneurial ecosystems. Ecosystems are traditionally viewed as resource pools. However, ecosystems guide entrepreneurial activities as well. The ecosystem which promotes disruptive fast growth would motivate entrepreneurs to apply AI technology for this end, while the ESG-oriented ecosystem would drive startups towards responsible innovation.

This is because the players such as accelerators, investors, universities, government, and corporate companies are essential components of the system where the scalability of AI technology occurs.

The theory further posits that startup scalability to become sustainable is a dynamic process. During the opportunity stage, the role of AI would be in helping entrepreneurs spot sustainability problems with market potential. During the experiment stage, AI would support model experimentation and testing. At the ecosystem stage, it would assist in resource and partner coordination. In the accountability stage, ESG intelligence would be supported by the use of AI. Finally, at the governance stage, the responsible routine would make the AI-based scalability of startups ethical and sustainable.

For emerging countries, there are several implications for sustainable entrepreneurship. The opportunities that come include the possibility to overcome resource limitations, leverage global information and apply AI to create sustainable solutions to problems. The risks of the lack of sustainable entrepreneurship based on AI include poor infrastructure, low data governance, fragmented institution, and lack of technical skills among others. This means that public policy and institutional development are important elements in AI-based sustainable entrepreneurship. This framework also highlights the relationship between automation and responsibility. Automation is at the core of AI capabilities; however, responsible scaling cannot happen without human judgement, stakeholder collaboration and ethical deliberation. The founders should not rely solely on automated tools for making sustainable business decisions. Rather, AI must supplement the decision-making processes of entrepreneurs.

Contributions to Technological Innovation and Entrepreneurship Literature

In addition, there are several contributions to technological innovation and entrepreneurship literature. First, this study develops a theory regarding AI capabilities

as ecosystem embedded scaling capabilities. Prior research tends to conceptualise AI as an internal technological resource. By contrast, this paper argues that scaling value creation using AI depends on complementary ecosystem dynamics, institutional frameworks and sustainable ESG accountability structures.

Furthermore, this paper extends the literature on entrepreneurial ecosystems by examining the role of AI in altering the way ecosystems participate in startup ventures. AI can help startups in identifying partner companies, coordinating ecosystem resources, and deciphering signals from the ecosystem. Moreover, AI can facilitate evaluations of startup scalability and sustainability potential.

Thirdly, the paper contributes to sustainable entrepreneurship literature by connecting sustainability with scalability. Sustainable entrepreneurship literature focuses on opportunities and impacts, whereas literature on startups focuses on growth. This paper contributes to both bodies of literature by combining them to provide a definition of sustainable startup scalability as growth maintaining ESG responsibility and innovation ethics.

Fourthly, the paper contributes to the responsible innovation literature by illustrating the need for responsible scaling governance in AI-powered startups. Governance for responsible scaling is not an afterthought; it is a precondition. While ignoring AI ethics, data governance, and ESG accountability might enable fast scaling, it makes startups prone to legitimacy crises.

Practical Implications

Implications for startup founders

Startups should regard AI technology as a strategic learning capacity rather than a means to automate processes. AI should be implemented to enhance startup opportunities identification, customer learning, process efficiency and ESG responsibilities. Finally, the founder must embed responsible innovation ethics from the very start of the venture. It includes data protection, transparency, bias monitoring, oversight and environmental awareness.

Sustainability criteria must be applied when assessing the feasibility of scalable ventures. Not only the speed at which the enterprise can acquire customers or reach markets, but also the speed at which it emits waste or engages stakeholders and respects their privacy needs to be accounted for. Responsible scaling implies that the founder takes impact assessment and management seriously from the outset.

Implications for accelerators and incubators

The work of accelerators and incubators should promote the principles of AI-assisted sustainable entrepreneurship by providing technical mentoring, responsible scaling metrics, responsible AI tools and access to sustainable partners. Evaluating the traction of a startup should go hand-in-hand with assessing its capability to scale responsibly. Educational programs may focus on issues of AI ethics, ESG, impact and business models.

Implications for investors
Investments in AI-supported entrepreneurial ventures should combine assessments of scalability with the evaluation of the venture's responsibility profile. The use of AI technology may have positive impacts, but also negative ones, including governance risks and regulatory consequences. Diligence procedures need to involve the assessment of AI governance systems, data handling and sustainability commitments made.

Implications for policymakers
Policymakers can foster AI-enabled ecosystems for sustainable entrepreneurship through investments in digital infrastructure, open sustainability data, regulatory sandboxes, AI responsibility guidelines and funding for green innovations. Governments can launch mission-led initiatives that drive startups towards the use of AI to address climate, health, educational, efficiency and inclusion challenges. The involvement of policymakers is particularly necessary in developing countries, where the ecosystem assets could be asymmetrically distributed.

Implications for universities and research institutions
The contribution of universities can be pivotal in terms of AI talent, sustainability know-how, technology commercialization and responsible innovation training. Research institutions can assist startups with test beds, data access and multidisciplinary competencies. University entrepreneurial programmes need to combine AI capabilities enhancement with innovative business models that focus on sustainability.

Limitations and Future Research Agenda

The current paper is conceptual and does not offer any empirical data. It seeks to develop an analytical framework and propositions for future research. Further empirical research will be required to investigate the relationships suggested in the AI-Enabled Sustainable Startup Scalability Framework.

For future quantitative research, there can be surveys conducted among AI-enabled startups in various ecosystems to assess the hypotheses put forward. Structural equation modelling might look into the possibility of whether sustainable business model experiments, ecosystem resource management and ESG intelligence affect the link between AI capabilities and sustainable scalability. Moderation analysis can examine the role of digital infrastructure readiness, data governance, absorptive capacity of the founders and institutional support.

Further qualitative research can involve longitudinal case studies of AI-enabled sustainable startups. It could assess the ways in which the AI was used by founders and its effects in different stages of venture development as well as how ecosystem actors facilitated responsible scaling of ventures. Comparative case study designs across various accelerators, cities or countries can further assess the ecosystem differences.

Future research should also look into the darker sides of AI-enabled startup scalability. They might consist in algorithmic biases, data extraction, energy. Future research

should therefore explore sector-specific applications of AI-driven sustainable scalable growth. Climate techs, healthtechs, edutechs, fintechs, agritechs, logistics firms and companies involved in the circular economy can benefit from sectorally oriented studies of AI-powered innovation ecosystems.

Conclusion

Artificial intelligence changes the context in which startups search for business opportunities, test their business models, activate resources and scale up. But scalable growth does not imply sustainability per se. Sustainability comes into play when scaled growth occurs within the innovation ecosystems aligned with environmental, social and governance objectives. The present paper proposed a theoretical model which shows how AI capabilities enable sustainable growth through five key mechanisms: opportunistic sensing, sustainable experimentation of business models, orchestration of ecosystem resources, ESG intelligence and responsible scaling practices.

The contributions of the paper for academic research lie in three areas: technological innovation, ecosystem research, and sustainable entrepreneurship. From the point of view of the Technovation audience, the primary contribution concerns the idea that artificial intelligence changes the nature of entrepreneurship. Growth should not just happen quickly; it should happen responsibly, intelligibly and sustainably. In other words, AI-powered entrepreneurship represents an ecosystem innovation challenge involving technological capability, sustainability accountability and responsible scaling.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work, AI-assisted language support was used to help organise the manuscript, improve readability and refine academic expression. The author reviewed, edited and verified the content and takes full responsibility for the final manuscript.

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Declaration of competing interest

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Data availability

No data were used for the research described in this conceptual paper.

Credit authorship contribution statement

Conceptualization; Methodology; Formal analysis; Writing - original draft; Writing - review and editing.

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