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Research Article

University-Led Innovation Ecosystems

Governance Models for University-Led Innovation Ecosystems in Sub-Saharan Africa: A Comprehensive Literature Review

Kaliba C[1*]

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[1*] Chabota Kaliba, Senior Lecturer and Consultant, Department of Civil and Environmental Engineering, University of Zambia, Zambia.

University-led innovation ecosystems have emerged as critical drivers of economic development, technological advancement, and entrepreneurial capacity building in sub-Saharan Africa (SSA). However, the governance models, institutional frameworks, and technology transfer mechanisms that enable these ecosystems remain underexplored and inadequately documented. This comprehensive literature review synthesizes evidence from 60 peer-reviewed studies published between 2000 and 2026 to examine governance frameworks, technology transfer mechanisms, university-industry linkages, and innovation infrastructure across SSA universities. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, this systematic review identified 574 records from seven database searches across SciSpace, Google Scholar and PubMed. After removing 110 duplicates, 464 unique records underwent abstract screening using seven criteria with a threshold score of ≥4.0, resulting in 61 papers being assessed in full-text. Full-text screening with a threshold of ≥4.5 yielded 56 papers for qualitative synthesis, representing diverse geographic contexts, including South Africa (n=16), Nigeria (n=10), Kenya (n=7), Rwanda (n=3), Ghana (n=4), and other SSA countries. Key findings reveal that successful university-led innovation ecosystems in SSA are characterised by multi-stakeholder collaboration frameworks (particularly the Triple Helix model), formalised technology transfer structures including Technology Transfer Offices (TTOs), dedicated innovation infrastructure such as science parks and incubators, and adaptive governance mechanisms responsive to local contexts. However, persistent challenges include limited funding, weak intellectual property frameworks, inadequate policy support, insufficient industry engagement, and capacity constraints. Emerging opportunities include digital platforms, regional collaboration networks, and progressive policy reforms. This review identifies four dominant governance models: (1) Triple Helix framework emphasising university-industry-government collaboration; (2) Entrepreneurial university models with embedded commercialisation functions; (3) Technology Transfer Office-centred approaches; and (4) Hybrid governance structures combining multiple stakeholder engagement mechanisms. These findings provide actionable insights for policymakers, university administrators, and development practitioners seeking to strengthen innovation ecosystems in resource-constrained environments.

Keywords: University-Led Innovation Ecosystems, Sub-Saharan Africa, Technology Transfer, Triple Helix Model, Technology Transfer Offices, Entrepreneurial Universities, Innovation Governance, University-Industry Collaboration, Innovation Infrastructure, Systematic Literature Review

Corresponding Author

Chabota Kaliba, Senior Lecturer and Consultant, Department of Civil and Environmental Engineering, University of Zambia, Zambia.
Email: chabota.kaliba@unza.ac.zm

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1. Introduction

1.1 Background and Context

SSA faces significant developmental challenges, including high unemployment rates, limited industrialisation, and persistent technology gaps that constrain economic growth and social progress. Universities in the region, including the University of Zambia are increasingly recognised as potential catalysts for innovation-driven development through their roles in knowledge creation, human capital development, and technology transfer (Kaliba, Muya and Mwiya, 2015; Kaliba, Mwambazi and Lungu, 2025). However, the transition from traditional teaching-focused institutions to entrepreneurial universities embedded within vibrant innovation ecosystems remains incomplete and unevenly distributed across regions.

Innovation ecosystems represent complex networks of interconnected actors, including universities, industries, governments, entrepreneurs, investors, and support organisations, that collectively enable the creation, diffusion, and commercialisation of new knowledge and technologies. University-led innovation ecosystems position higher-education institutions as anchor organisations that coordinate and facilitate these interactions through governance structures, technology transfer mechanisms, physical infrastructure, and policy frameworks (Mwanaumo *et al.*, 2017; Hailu, 2024; Osayande *et al.*, 2025).

University-led innovation ecosystems in SSA operate within unique contextual constraints, including limited research funding, weak intellectual property protection, nascent entrepreneurial cultures, fragmented policy environments, and capacity gaps in innovation management (Bronstein and Bissett, 2021; Ujam, 2024). These challenges necessitate governance models that are adaptive, resource-efficient, and contextually appropriate, while drawing on international best practices.

1.2 Research Objectives

This comprehensive literature review addresses the following research objectives:

i. To systematically identify and synthesize evidence on governance frameworks and models implemented by universities in SSA to establish and manage innovation ecosystems.

ii. To examine how university-industry linkages and technology transfer mechanisms within SSA universities contribute to innovation ecosystem development.

iii. To analyse the organisational structures and governance arrangements adopted by universities for managing science and technology parks, incubators and accelerators.

iv. To assess how different governance models impact innovation outputs, technology commercialisation, and regional economic development.

v. To identify the institutional frameworks, policies, and stakeholder engagement mechanisms employed by SSA universities to facilitate effective innovation ecosystem governance.

1.3 Significance of the Study

This systematic review contributes to academic scholarship and practical policy development in several ways. First, it provides the most comprehensive synthesis of empirical evidence on university-led innovation ecosystem governance in SSA to date, addressing a significant gap in the literature. Second, it identifies successful governance models and mechanisms that can inform institutional transformation efforts across regions. Third, it highlights the persistent challenges and emerging opportunities that require the attention of policymakers, university administrators, and development partners. Finally, it establishes a foundation for future research on innovation ecosystem governance in resource-constrained settings.

2. Methodology

2.1 PRISMA Protocol

This systematic literature review followed the PRISMA 2020 guidelines to ensure transparency, reproducibility and methodological rigor. The PRISMA framework guided all phases of the review, including protocol development, literature search, screening, data extraction, and synthesis.

2.2 Search Strategy

A comprehensive search strategy was developed to identify relevant literature on governance models for university-led innovation ecosystems in SSA. Seven database searches were conducted across three platforms:

i. SciSpace (four queries): Two queries targeting standard search, one for full-text search, and one for library search. Search terms included combinations of university governance frameworks, innovation ecosystems, technology transfer, university-industry linkages, entrepreneurship ecosystems, science and technology parks, incubators, and accelerators in SSA.
ii. Google Scholar (two queries): Broad searches covering academic institutions, organisational structures, institutional frameworks, innovation management, and technology commercialisation across SSA sub-regions.
iii. PubMed (one query): Focused search using Medical Subject Headings (MeSH) terms and title/abstract fields for university governance, innovation, and technology transfer in Africa.

The search covered publications from 2000 to 2026, capturing over two decades of research on university-led innovation ecosystems in SSA. A total of 574 records were identified through database searches.

2.3 Eligibility Criteria

Studies were included if they met the following criteria:

i. Inclusion criteria:

a. Focus on universities or higher-education institutions in SSA
b. Address governance models, frameworks, or structures for innovation ecosystems
c. Examine technology transfer, university-industry linkages, or entrepreneurship support mechanisms
d. Published between 2000 and 2026

ii. Exclusion criteria:

a. Studies not focused on SSA
b. Studies not addressing university-led innovation ecosystems or governance
c. Non-peer-reviewed sources without substantial empirical content

2.4 Screening Process

After removing 110 duplicates, 464 unique records underwent a two-stage screening process:

i. Abstract screening: Seven criteria (four inclusion, three exclusion) with a threshold score of ≥4.0 on a 0-5 scale. This stage resulted in 61 papers advancing to full-text assessment.

ii. Full-text screening: More stringent criteria were applied with a threshold score of ≥4.5, yielding 56 papers for inclusion in the qualitative synthesis.

The screening process was designed to balance comprehensiveness with quality, ensuring that included studies provided substantive evidence of governance models and innovation ecosystem mechanisms.

2.5 Data Extraction

Data extraction focused on six key dimensions:

i. Governance model type: Frameworks and structures used to organise and coordinate innovation ecosystem activities
ii. Technology transfer mechanisms: Formal and informal processes for moving knowledge and technologies from universities to industry and society
iii. University-industry linkage types: Forms of collaboration and partnership between academic and industrial actors
iv. Innovation infrastructure: Physical and organisational structures supporting innovation activities
v. Key findings and outcomes: Empirical results, impacts, and lessons learned
vi. Geographic focus: Specific SSA countries and contexts examined

This structured approach enabled systematic comparison across studies and identification of patterns, trends, and gaps in the literature.

3. Thematic Analysis of Results

3.1 Geographic Distribution and Context

The 56 included studies represent diverse geographic contexts across SSA, with significant variations in research intensity and innovation ecosystem maturity. South Africa dominates the literature with 16 studies, reflecting its more developed research infrastructure, stronger intellectual property frameworks, and longer history of university-industry collaboration (Thamae, Thamae and Thamae, 2016; Ncanywa and Dyantyi, 2022; Kruger and Steyn, 2024; Stephen and Aigbavboa, 2025; Suleiman, 2025; Zaidi and Baptist, 2025). Nigeria follows with ten studies, driven by its large higher-education sector and a growing entrepreneurial ecosystem (Lyken-Segosebe *et al.*, 2020; Jaeger *et al.*, 2025;

Adebayo, Amosu and Aluko-lokun, 2026). Kenya contributed seven studies, highlighting its emergence as an innovation hub, particularly in digital technology and agricultural innovation (Liche and Braun Střelcová, 2023; Adjimah *et al.*, 2026). Ghana (four studies), Rwanda (three studies), Tanzania (three studies), and Uganda (two studies) represent important case studies of innovation ecosystem development in smaller economies (Cherunya and Ahlborg, 2020; Mukasa and Sangwa, 2025; Osayande *et al.*, 2025; Sassi and Mshenga, 2025).

This geographic distribution reflects both research capacity differences and variations in innovation ecosystem maturity across SSA. South Africa's dominance in the literature corresponds to its relatively advanced National System of Innovation, established TTOs, and supportive policy frameworks, including the Intellectual Property Rights from Publicly Financed Research and Development Act (IPR-PFRD Act) of 2008 (Uctu and Essop, 2020; Zaidi and Musoke, 2020). In contrast, studies from other countries often document earlier stages of ecosystem development, highlighting challenges of establishing basic infrastructure and governance mechanisms (Ujam, 2024; Osayande *et al.*, 2025).

3.2 Governance Models

The literature identifies four dominant governance models for university-led innovation ecosystems in SSA, each with distinct characteristics, strengths, and contextual applications.

3.2.1 Triple Helix Model

The Triple Helix model, which emphasises collaborative relationships among universities, industry, and government, has emerged as the most frequently discussed governance framework in SSA literature (Bansi, 2016; Okonofua, Odubanjo and Balogun, 2020; Hailu, 2024; Fussy, 2026). This model positions universities as entrepreneurial actors who actively engage with industry partners and government agencies to co-create innovative outcomes. Studies from Ethiopia, South Africa, and Kenya have demonstrated how Triple Helix relationships facilitate technology transfer, joint research initiatives, and policy development (Liche and Braun Střelcová, 2023; Hailu, 2024; Dzingirai, 2025).

Hailu (2024) found that intermediary organisations, including TTOs, collaborative research centres, incubators, and science parks, enhance university-industry collaboration within the Triple Helix framework. The integration of these functions transforms universities from isolated knowledge producers into active participants in regional innovation systems. However, implementation challenges include weak institutional linkages, limited government coordination, and insufficient industry engagement capacity (Bansi, 2016; Fussy, 2026).

3.2.2 Entrepreneurial University Model

The entrepreneurial university model represents a fundamental transformation in institutional mission, structure, and culture to embed innovation and commercialisation functions alongside traditional teaching and research activities (Kruger and Steyn, 2020; Adelowo, Siyanbola and Ibrahim, 2023; Chfadi, Abdulkader and Chirinda, 2025). Studies from South Africa, Botswana, and Uganda document efforts to develop entrepreneurial universities through strategic planning, organisational restructuring, and capacity building (Gachie and Govender, 2017; Kruger and Steyn, 2020; Nyemba, Mbohwa and Carter, 2021b).

Kruger and Steyn (2020) analysed South African universities and identified key practices for enhancing technology transfer through entrepreneurial development, including dedicated innovation spaces, entrepreneurship education programmes, and commercialisation support services. The entrepreneurial university model requires significant institutional change, including revised promotion criteria recognising commercialisation activities, flexible intellectual property policies, and investment in innovation infrastructure (Chfadi, Abdulkader and Chirinda, 2025; Mpanju and Pistoriusf, 2026).

3.2.3 Technology Transfer Office (TTO) Model

TTOs represent formalised organisational structures dedicated to managing intellectual property, facilitating industry partnerships, and supporting commercialisation of university research (Uctu and Essop, 2020; Zaidi and Musoke, 2020; Mukasa and Sangwa, 2025). The TTO model is most developed in South Africa, where the IPR-PFRD Act of 2008 mandated establishment of technology transfer functions at publicly funded research institutions (Uctu and Essop, 2020; Zaidi and Musoke, 2020).

Mpanju and Pistoriusf (2026)'s study of South African universities found that TTOs play crucial roles in patenting and commercialisation of research results, though effectiveness varies significantly across institutions based on resources, expertise, and institutional support. Challenges include limited commercialisation funding, weak industry networks, and insufficient technical expertise in intellectual property management and business development (Uctu and Essop, 2020; Mpanju and Pistoriusf, 2026). Studies from other SSA countries document efforts to establish TTO functions, often with support from international development partners (Osayande *et al.*, 2025; Shao *et al.*, 2025).

3.2.4 Hybrid and Adaptive Governance Structures

Many SSA universities adopt hybrid governance structures that combine elements of multiple models to address local contexts and resource constraints (Bafon *et al.*, 2024; Bokor, 2024; Sagwa *et al.*, 2024). These adaptive approaches may integrate Triple Helix collaboration principles with entrepreneurial university transformation strategies and formalised TTO functions, while remaining flexible to evolving circumstances.

Studies from Rwanda, Tanzania, and Uganda highlight the importance of adaptive governance that responds to limited resources, weak institutional capacity, and nascent innovation ecosystems (Gachie and Govender, 2017; Mukasa and Sangwa, 2025; Osayande *et al.*, 2025). Osayande *et al.* (2025) advocated an AI-driven knowledge and technology transfer framework that combines structured university-industry partnerships, digital intellectual property management, and government incentives within an integrated governance structure. This represents an emerging trend toward technology-enabled governance models that leverage digital platforms to overcome traditional barriers.

3.3 Technology Transfer Mechanisms

Technology transfer mechanisms represent the operational processes through which universities move knowledge, technology, and innovation from academic research to industrial application and societal benefit. The literature identifies multiple mechanisms operating across SSA universities with varying levels of formalisation and effectiveness.

3.3.1 Formal TTOs

Formal TTOs are the primary institutional mechanism for managing technology transfer in more developed SSA innovation ecosystems, particularly in South Africa (Uctu and Essop, 2020; Zaidi and Musoke, 2020; Mpanju and Pistoriusf, 2026). These offices typically provide services, including intellectual property assessment and protection, patent filing and management, licencing negotiations, industry partnership facilitation, and commercialisation support. However, studies consistently report challenges, including limited funding, insufficient staffing with appropriate expertise, weak industry networks, and low volumes of commercially viable inventions (Uctu and Essop, 2020; Mpanju and Pistoriusf, 2026).

The South African experience following the IPR-PFRD Act of 2008 demonstrates both opportunities and challenges of formalised technology transfer. While the Act established clear ownership of intellectual property from publicly funded research and mandated TTO establishment, implementation has been uneven, with significant variation in TTO capacity and effectiveness across institutions (Uctu and Essop, 2020; Zaidi and Musoke, 2020). Smaller universities and those in rural areas face challenges in building viable TTO operations.

3.3.2 Licensing and Patenting Systems

Intellectual property protection through patents and subsequent licencing represents a traditional technology transfer mechanism, although its application in SSA faces significant constraints (Malele, Letsoalo and Mafu, 2022; Mpanju and Pistoriusf, 2026). Studies document low patenting rates from SSA universities due to limited research commercialisation potential, high costs of patent filing and maintenance, weak intellectual property enforcement, and insufficient expertise in patent strategy (Osayande *et al.*, 2025; Mpanju and Pistoriusf, 2026).

Where patenting occurs, licencing arrangements often fail to generate significant revenue owing to limited industry demand, weak negotiation capacity, and preference for informal knowledge-transfer channels (Uctu and Essop, 2020; Malele, Letsoalo and Mafu, 2022). This suggests that while formal IP mechanisms are important for certain high-value innovations, alternative technology-transfer approaches may be more appropriate for many SSA contexts.

3.3.3 Spin-off Company Creation

University spin-off companies represent an important technology transfer mechanism that directly commercialises research through new venture creation (Mashau and Fields, 2022; Sagwa *et al.*, 2024). Studies from South Africa, Nigeria, and Kenya document spin-off activities, although volumes remain low compared to developed countries (Fadeyi *et al.*, 2019; Sagwa *et al.*, 2024). Barriers to spin-off creation include limited entrepreneurial culture among academics, insufficient seed funding, weak business support services, and regulatory obstacles (Mashau and Fields, 2022; Sagwa *et al.*, 2024).

Urban and Seely (2023)'s study of academic spin-offs in South Africa found that contextual factors including institutional support, access to finance, and entrepreneurial ecosystems significantly influence spin-off success. Successful spin-off support requires comprehensive services, including entrepreneurship training, business development assistance, seed funding, and ongoing mentorship.

3.3.4 Collaborative Research and Consulting

Informal technology transfer through collaborative research projects and consulting arrangements is the most common mechanism in SSA universities (Mensah and Gordon, 2020; Hailu, 2024; Sangwa *et al.*, 2025). These arrangements enable knowledge exchange, capacity building, and problem-solving partnerships without requiring formal IP management or commercialisation structures. Studies have highlighted the importance of these informal channels in building university-industry relationships and demonstrating research relevance (Mensah and Gordon, 2020; Hailu, 2024).

However, informal mechanisms also present challenges, including lack of institutional recognition, limited revenue capture, potential conflicts of interest, and missed opportunities for formal IP protection and commercialisation (Mensah and Gordon, 2020; Sangwa *et al.*, 2025). Effective governance requires balancing flexibility of informal arrangements with appropriate oversight and strategic alignment.

3.4 University-Industry Linkages

University-industry linkages constitute the relational infrastructure connecting academic and industrial actors within innovation ecosystems. The literature documents diverse linkage types with varying levels of formalisation, intensity, and strategic alignment.

3.4.1 Collaborative Research Centres

Collaborative research centres represent formalised structures for sustained university-industry research partnerships, often focused on specific sectors or technologies (Mukhwana, 2017; Hailu, 2024). These centres typically involve joint governance, shared funding, co-located researchers and defined research agendas aligned with industry needs. Studies from South Africa and Kenya highlight successful collaborative research centres in sectors including agriculture, health technology, and renewable energy (Mukhwana, 2017; Liche and Braun Střelcová, 2023).

The effectiveness of collaborative research centres depends on sustained commitment from all partners, adequate funding, clear governance structures, and alignment between academic research interests and industry needs (Mukhwana, 2017; Hailu, 2024). The challenges include maintaining long-term industry engagement, balancing academic freedom with applied research demands, and ensuring equitable benefit sharing.

3.4.2 Industrial Chairs and Embedded Professionals

Industrial chairs and embedded industry professionals represent mechanisms for deepening university-industry integration through personnel exchanges (Bokor, 2024; Shange, Zogli and Dlamini, 2026). Industrial chairs involve industry-funded academic positions focused on research areas of strategic importance to sponsoring companies. Embedded professionals bring industry expertise to universities through adjunct appointments, visiting positions, or joint appointments.

These mechanisms facilitate knowledge transfer, enhance research relevance, provide student mentorship and employment pathways, and build sustained relationships between institutions (Bokor, 2024; Shange, Zogli and Dlamini, 2026). However, implementation in SSA contexts faces challenges, including limited industry capacity to fund chairs, concerns about academic independence, and administrative complexities.

3.4.3 Internships and Work-Integrated Learning

Student internships and work-integrated learning programs are important linkage mechanisms that build human capital, facilitate knowledge exchange, and create employment pathways (Beugré, 2017; Bokor, 2024). Studies emphasise the dual benefits of these programs for students (practical skills, industry exposure, employment opportunities) and industry (access to talent, fresh perspectives, university relationships) (Beugré, 2017).

Effective internship programs require structured coordination, clear learning objectives, adequate supervision, and mechanisms for capturing and sharing insights (Beugré, 2017; Bokor, 2024). Challenges include limited industry capacity to host interns, geographic constraints, and ensuring meaningful learning experiences rather than routine task completion.

3.4.4 Informal Consultancy and Advisory Relationships

Informal consultancy and advisory relationships represent the most common form of university-industry linkage across SSA, though often undocumented and unmanaged at institutional level (Mensah and Gordon, 2020; Sangwa *et al.*, 2025). Individual academics provide consulting services, serve on company boards, or offer informal advice based on their expertise. While these relationships build social capital and demonstrate research relevance, they may not contribute to institutional objectives or generate institutional revenue (Mensah and Gordon, 2020; Sangwa *et al.*, 2025)

Governance challenges include managing potential conflicts of interest, ensuring appropriate institutional recognition and benefit sharing, and leveraging informal relationships for strategic institutional partnerships [(Mensah and Gordon, 2020; Sangwa *et al.*, 2025). Some universities are developing policies to formalise and support consulting activities while maintaining appropriate oversight.

3.5 Innovation Infrastructure

Physical and organisational innovation infrastructure provides the spaces, facilities, and support services that enable innovation ecosystem activities. The literature documents diverse infrastructure types across SSA universities, with varying levels of development and effectiveness.

3.5.1 Science and Technology Parks

Science and technology parks represent dedicated zones that co-locate university research facilities, technology companies, and support services to facilitate knowledge exchange and commercialisation (Cullen, Calitz and Chetty, 2020; Nyemba, Mbohwa and Carter, 2021a). Studies from South Africa, Nigeria, and Kenya document science park initiatives, though many remain in planning or early implementation stages (Cullen, Calitz and Chetty, 2020; Nyemba, Mbohwa and Carter, 2021a; Ujam, 2024).

Ujam (2024)'s study of technology park development around Nigerian engineering faculties proposes a model managed by professionals, lecturers, and students to enhance engineering skills, innovation, and self-reliance. This approach emphasises integration with academic programmes and student engagement in innovation activities. Challenges include securing adequate land and facilities, attracting tenant companies, generating sustainable revenue, and maintaining relevance to university research and education missions (Nyemba, Mbohwa and Carter, 2021a; Ujam, 2024).

3.5.2 Business Incubators

Business incubators provide physical space, business support services, mentorship, and networking opportunities for early-stage ventures, including university spin-offs and student startups (Kruss and Gastrow, 2015; Lyken-Segosebe *et al.*, 2020; Adjimah *et al.*, 2026). Studies document incubator initiatives across SSA universities, with varying models including university-managed incubators, partnerships with external incubator operators, and virtual incubation programs (Kruss and Gastrow, 2015; Lyken-Segosebe *et al.*, 2020; Adjimah *et al.*, 2026).

Lyken-Segosebe *et al.* (2020) studied technology business incubation at a Botswana university and identified lessons for sponsoring universities, including the importance of clear governance structures, adequate resources, experienced management, and integration with academic programs. Adjimah *et al.* (2026) found positive impacts on indigenous innovation performance in Ghanaian university incubators, although effectiveness depends on incubator quality, support services, and industry linkages.

3.5.3 Accelerators and Innovation Hubs

Accelerators provide intensive, time-bound support programs for startups, typically including mentorship, training, networking, and potential investment (Pitso, 2019; Hadjitchoneva and Nanfosso, 2025). Innovation hubs represent flexible, collaborative spaces that support diverse innovation activities, including co-working, events, training, and community building (Pitso, 2019; Dzingirai, 2025).

Mukasa and Sangwa (2025)'s study of African startup accelerators found that university partnerships signal venture quality and drive funding growth, particularly important in capital-scarce environments. Dzingirai (2025) demonstrated how design-thinking approaches can foster entrepreneurship through experiential learning and problem-solving methodologies in university-based innovation hubs in Zimbabwe. Challenges include ensuring financial sustainability, maintaining relevance to evolving startup needs, and measuring impact beyond immediate outputs (Pitso, 2019; Dzingirai, 2025; Mukasa and Sangwa, 2025).

3.5.4 Makerspaces and Fabrication Laboratories

Makerspaces and fabrication laboratories provide access to tools, equipment, and technical expertise for prototyping and product development (Tweheyo *et al.*, 2024). These facilities support hands-on learning, experimentation and innovation across disciplines. While less documented in SSA literature than other infrastructure types, emerging studies highlight their potential for democratising innovation and supporting hardware-focused ventures (Tweheyo *et al.*, 2024).

Effective makerspaces require appropriate equipment, technical support staff, clear access policies, and integration with academic programs and entrepreneurial support services (Tweheyo *et al.*, 2024). Sustainability challenges include equipment maintenance, consumable costs, and ensuring utilisation by diverse groups.

3.6 Key Challenges and Barriers

The literature identifies multiple challenges and barriers that constrain university-led innovation ecosystem development in SSA. Understanding these obstacles is essential for designing effective governance models and support mechanisms.

3.6.1 Limited Funding and Resources

Insufficient funding emerges as the most frequently cited challenge across studies, affecting all aspects of innovation ecosystem development (Bronstein & Bissett, 2021; Ujam, 2024; Osayande *et al.*, 2025). Universities face constraints in research funding, infrastructure investment, technology transfer operations, and entrepreneurship support services. Limited government research budgets, weak industry R&D investment, and competition for scarce resources create persistent funding gaps (Bronstein & Bissett, 2021; Osayande *et al.*, 2025).

Studies have documented specific funding challenges, including inadequate TTO budgets that limit staffing and operations (Uctu and Essop, 2020; Mpanju and Pistoriusf, 2026), insufficient seed funding for spin-offs and startups (Mashau and Fields, 2022; Sagwa *et al.*, 2024), inability to invest in modern research equipment and facilities (Bronstein and Bissett, 2021; Ujam, 2024), and limited resources for innovation infrastructure development and maintenance (Cullen, Calitz and Chetty, 2020; Nyemba, Mbohwa and Carter, 2021a). These funding constraints necessitate creative approaches, including international partnerships, development partner support, and revenue-generating activities.

3.6.2 Weak Intellectual Property Frameworks

Inadequate intellectual property protection and management capacity constrain technology transfer and commercialisation across SSA (Uctu and Essop, 2020; Zaidi and Musoke, 2020; Osayande *et al.*, 2025). Challenges include weak IP enforcement, high costs of patent filing and maintenance, limited expertise in IP strategy and management, and unclear ownership arrangements for collaborative research (Uctu and Essop, 2020; Osayande *et al.*, 2025).

Even in South Africa, with its relatively developed IP framework, studies have documented implementation challenges following the IPR-PFRD Act, including institutional capacity gaps, unclear benefit-sharing arrangements, and tensions between open science principles and commercialisation objectives (Uctu and Essop, 2020; Zaidi and Musoke, 2020). Other SSA countries face more fundamental challenges in establishing basic IP infrastructure and expertise (Mukasa and Sangwa, 2025; Osayande *et al.*, 2025).

3.6.3 Inadequate Policy Support

Inconsistent or absent policies at national and institutional levels create uncertainty and limit innovation ecosystem development (Gachie and Govender, 2017; Bronstein and Bissett, 2021; Osayande *et al.*, 2025). Policy gaps include lack of clear technology transfer policies, absence of incentives for commercialisation activities, unclear promotion criteria recognising entrepreneurial activities, and insufficient coordination across government agencies (Bronstein and Bissett, 2021; Osayande *et al.*, 2025).

Studies have emphasised the need for comprehensive policy frameworks that address IP ownership, benefit sharing, conflict of interest management, industry engagement, and entrepreneurship support (Gachie and Govender, 2017; Zaidi and Musoke, 2020; Osayande *et al.*, 2025). Effective policies must balance multiple objectives, including knowledge dissemination, commercialisation, academic freedom, and public benefit.

3.6.4 Insufficient Industry Engagement

Limited industry participation in university-led innovation ecosystems reflects multiple factors, including weak industry R&D capacity, preference for imported technologies, limited awareness of university capabilities, and lack of trust in university partnerships (Mensah and Gordon, 2020; Bronstein and Bissett, 2021; Hailu, 2024). Studies document challenges in attracting industry partners, sustaining engagement beyond initial projects, and demonstrating research relevance to industry needs (Mensah and Gordon, 2020; Hailu, 2024).

Building effective university-industry linkages requires sustained relationship development, value demonstration, flexible engagement mechanisms, and addressing industry concerns about IP, confidentiality, and timelines (Mensah and Gordon, 2020; Hailu, 2024; Sangwa *et al.*, 2025). Some studies highlight the role of intermediary organisations and boundary-spanning individuals in facilitating these connections (Mukhwana, 2017; Hailu, 2024).

3.6.5 Capacity Constraints

Human capacity constraints affect all aspects of innovation ecosystem governance and operations (Gachie and Govender, 2017; Bronstein and Bissett, 2021; Osayande *et al.*, 2025).

Universities lack sufficient personnel with expertise in technology transfer, IP management, business development, entrepreneurship support, and innovation ecosystem coordination (Uctu and Essop, 2020; Osayande *et al.*, 2025; Mpanju and Pistoriusf, 2026). Academic staff often lack training in commercialisation, entrepreneurship and industry engagement (Gachie and Govender, 2017; Bronstein and Bissett, 2021).

Capacity-building initiatives, including training programs, international exchanges, and mentorship, are essential but require sustained investment and institutional commitment (Bronstein and Bissett, 2021; Osayande *et al.*, 2025). Studies emphasise the importance of developing local expertise rather than relying solely on external consultants or international models that may not fit local contexts (Gachie and Govender, 2017; Osayande *et al.*, 2025).

4. Discussion on Governance Frameworks

4.1 The Triple Helix Model in SSA Context

The Triple Helix model's prominence in SSA literature reflects its conceptual appeal as a framework for multi-stakeholder collaboration in innovation ecosystems (Bansi, 2016; Hailu, 2024; Fussy, 2026). The model's emphasis on university-industry-government relationships aligns with development priorities, emphasising partnerships and coordinated action. However, implementation in SSA contexts reveals significant adaptations and challenges compared to the model's origins in developed countries.

Studies demonstrate that effective Triple Helix relationships in SSA require strong intermediary organisations to facilitate connections, coordinate activities, and build trust among partners (Mukhwana, 2017; Hailu, 2024). TTOs, collaborative research centres, incubators, and science parks serve these intermediary functions, although their capacity varies significantly across contexts (Hailu, 2024). The model's success depends on all three helices having sufficient capacity and commitment to engage meaningfully, which is often not the case in resource-constrained SSA environments (Bansi, 2016; Fussy, 2026).

Adaptations of the Triple Helix model in SSA include greater emphasis on international development partners as a fourth helix, recognition of informal sector actors and community organisations, and acknowledgment of diaspora networks as important connectors (Bansi, 2016; Fussy, 2026). These adaptations reflect the reality that innovation ecosystems in SSA operate within broader development contexts and must engage diverse stakeholders beyond the traditional three helices.

4.2 Entrepreneurial University Transformation

The entrepreneurial university model represents an aspirational framework for many SSA institutions seeking to enhance their economic and social impact (Kruger and Steyn, 2020; Adelowo, Siyanbola and Ibrahim, 2023; Chfadi, Abdulkader and Chirinda, 2025). However, transformation toward entrepreneurial universities faces significant institutional, cultural, and resource barriers in SSA context.

Studies document various approaches to entrepreneurial university development, including strategic planning processes, organisational restructuring, policy reforms, and capacity-building initiatives (Gachie and Govender, 2017; Kruger and Steyn, 2020; Nyemba, Mbohwa and Carter, 2021b). Successful transformation requires leadership commitment, stakeholder engagement, resource allocation, and sustained effort over several years (Kruger and Steyn, 2020; Chfadi, Abdulkader and Chirinda, 2025). Challenges include resistance from faculty who prefer traditional academic roles, limited resources for new initiatives, unclear promotion criteria, and tensions between entrepreneurial activities and traditional academic values (Nyemba, Mbohwa and Carter, 2021b; Chfadi, Abdulkader and Chirinda, 2025).

The literature suggests that entrepreneurial university transformation in SSA must be contextually adapted rather than directly importing models from developed countries (Gachie and Govender, 2017; Kruger and Steyn, 2020). Adaptations include emphasis on social entrepreneurship and development impact alongside commercial outcomes, recognition of diverse knowledge systems, including indigenous knowledge, and integration with community engagement missions (Gachie and Govender, 2017; Kruger and Steyn, 2020).

The entrepreneurial university in the SSA context may look different from Western models while still achieving enhanced economic and social impact.

4.3 TTOs Models

TTOs represent the most formalised governance mechanism for managing university innovation and commercialisation activities (Uctu and Essop, 2020; Zaidi and Musoke, 2020; Mpanju and Pistoriusf, 2026). The South African experience with mandated TTO establishment following the IPR-PFRD Act provides important lessons for other SSA countries considering similar approaches.

Studies reveal significant variation in TTO effectiveness across South African universities based on institutional size, research intensity, resource allocation, and management expertise (Uctu and Essop, 2020; Mpanju and Pistoriusf, 2026). Larger, research-intensive universities with substantial TTO budgets and experienced staff achieve better outcomes in terms of patents filed, licences executed, and spin-offs created (Mpanju and Pistoriusf, 2026). Smaller universities struggle to justify dedicated TTO operations given low volumes of commercially viable inventions and limited resources (Uctu and Essop, 2020).

Emerging alternative TTO models in SSA include shared services across multiple institutions, partnerships with external technology transfer organisations, and virtual TTO operations leveraging digital platforms (Osayande *et al.*, 2025; Shao *et al.*, 2025). These models attempt to achieve economies of scale and access specialised expertise while reducing costs for individual institutions. However, effectiveness depends on coordination mechanisms, trust among participating institutions, and appropriate governance structures (Shao *et al.*, 2025)

4.4 Hybrid and Adaptive Governance Structures

The prevalence of hybrid governance structures in SSA reflects pragmatic adaptation to resource constraints, institutional capacity limitations, and evolving innovation ecosystems (Bafon *et al.*, 2024; Bokor, 2024; Sagwa *et al.*, 2024). Rather than adopting a single governance model, many universities combine elements of multiple approaches to create contextually appropriate structures.

Hybrid models may integrate Triple Helix collaboration principles with entrepreneurial university transformation strategies and formalised TTO functions, while maintaining flexibility to adjust as circumstances evolve (Bafon *et al.*, 2024; Sagwa *et al.*, 2024). This adaptive approach recognises that innovation ecosystem governance is not static but must respond to changing contexts, emerging opportunities, and lessons learned from experience (Bafon *et al.*, 2024; Osayande *et al.*, 2025).

Studies emphasise the importance of learning and adaptation in innovation ecosystem governance (Bafon *et al.*, 2024; Osayande *et al.*, 2025). Effective governance structures include mechanisms for monitoring performance, gathering stakeholder feedback, experimenting with new approaches, and adjusting strategies based on evidence (Bafon *et al.*, 2024). This learning orientation is particularly important in SSA, where innovation ecosystems are still developing and best practices are still emerging.

4.5 Policy and Institutional Frameworks

Effective governance of university-led innovation ecosystems requires supportive policy and institutional frameworks at multiple levels, including national innovation policy, higher-education policy, institutional policies, and operational procedures (Gachie and Govender, 2017; Zaidi and Musoke, 2020; Bronstein and Bissett, 2021; Osayande *et al.*, 2025).

National-level policies establish the overall framework for innovation ecosystem development, including IP ownership rules, research funding mechanisms, tax incentives for R&D, and coordination structures (Zaidi and Musoke, 2020). The South African IPR-PFRD Act demonstrates how national policy can drive institutional change, though implementation challenges highlight the importance of adequate resources, capacity building, and stakeholder engagement (Uctu and Essop, 2020; Zaidi and Musoke, 2020).

Institutional policies translate national frameworks into operational guidance for university activities, including IP ownership and benefit sharing, conflict-of-interest management, promotion criteria recognising commercialisation, industry engagement procedures, and entrepreneurship support (Gachie and Govender, 2017; Osayande *et al.*, 2025).

Studies emphasise the need for clear, consistent policies that balance multiple objectives and provide appropriate incentives for desired behaviours (Gachie and Govender, 2017; Osayande *et al.*, 2025).

Operational procedures implement policies through specific processes, forms, and workflows for activities such as invention disclosure, IP assessment, patent filing, licencing negotiation, spin-off creation, and industry partnership management (Uctu and Essop, 2020; Mpanju and Pistoriusf, 2026). Effective procedures are clear, efficient, and user-friendly while maintaining appropriate oversight and compliance (Mpanju and Pistoriusf, 2026).

5. Emerging Opportunities and Innovations

5.1 Digital Transformation and AI-Driven Frameworks

Digital technologies and artificial intelligence present emerging opportunities for transforming innovation ecosystem governance in SSA (Letsebe, Ebewo and Nesamvuni, 2024; Osayande *et al.*, 2025). Osayande (2025) proposed an AI-driven knowledge and technology transfer framework at the University of Rwanda, exemplifying this trend by incorporating AI-powered research matchmaking, digital IP management and online collaboration platforms.

Digital platforms can address traditional barriers, including geographic distance, limited personnel capacity, and information asymmetries, by enabling virtual collaboration, automated processes, and data-driven decision-making (Letsebe, Ebewo and Nesamvuni, 2024; Osayande *et al.*, 2025). Examples include online portals that connect researchers with industry partners, digital IP management systems, virtual incubation programs, and data analytics for innovation ecosystem monitoring (Osayande *et al.*, 2025).

However, digital transformation requires investment in technology infrastructure, digital literacy development, and change management to ensure adoption and effective use (Letsebe, Ebewo and Nesamvuni, 2024). Studies emphasise the importance of designing digital solutions appropriate to local contexts rather than simply importing systems from developed countries (Osayande *et al.*, 2025).

5.2 Regional Collaboration Networks

Regional collaboration networks represent an important opportunity for SSA universities to achieve economies of scale, share resources and expertise, and collectively address common challenges (Khumalo and Du Plessis, 2024; Shao *et al.*, 2025). Examples include regional technology transfer networks, shared innovation infrastructure, collaborative research programs, and joint entrepreneurship initiatives (Khumalo and Du Plessis, 2024; Shao *et al.*, 2025).

Regional approaches can enable smaller universities to access specialised services and expertise that would be unaffordable individually, facilitate cross-border industry partnerships, and strengthen advocacy for supportive policies (Shao *et al.*, 2025). However, effective regional collaboration requires coordination mechanisms, trust among participating institutions, and sustainable funding models (Shao *et al.*, 2025).

Studies document emerging regional initiatives, including the African Research Universities Alliance (ARUA), regional innovation hubs, and cross-border research collaborations (Khumalo and Du Plessis, 2024). These initiatives demonstrate the potential for regional approaches while highlighting coordination challenges and the need for sustained commitment from participating institutions and supporting organisations.

5.3 Sector-Specific Innovation Ecosystems

Sector-specific innovation ecosystems focused on priority areas such as agriculture, health, renewable energy, and digital technology represent an emerging trend in SSA (Kruss and Visser, 2017; Liche and Braun Střelcová, 2023; Jjagwe *et al.*, 2024). These ecosystems bring together universities, industry actors, government agencies, and other stakeholders to address shared sectoral challenges and opportunities.

Studies document successful sector-specific initiatives including agricultural innovation platforms, health technology innovation hubs, and renewable energy research centres (Kruss and Visser, 2017; Liche and Braun Střelcová, 2023; Jjagwe *et al.*, 2024). These focused ecosystems can achieve greater impact by concentrating resources, building specialised expertise, and aligning with national development priorities (Kruss and Visser, 2017; Jjagwe *et al.*, 2024).

Governance of sector-specific ecosystems requires coordination across multiple institutions and stakeholders, sustained funding, and mechanisms for translating research into practical applications (Kruss and Visser, 2017; Liche and Braun Střelcová, 2023). Success factors include strong leadership, clear strategic focus, industry engagement, and demonstration of tangible impacts (Kruss and Visser, 2017; Jjagwe *et al.*, 2024).

6. Conclusion

6.1 Summary of Key Findings

This comprehensive systematic literature review synthesised evidence from 60 studies on governance models of university-led innovation ecosystems in SSA. The review identified four dominant governance models: the Triple Helix framework emphasising university-industry-government collaboration; entrepreneurial university models embedding commercialisation functions; Technology Transfer Office-centred approaches; and hybrid governance structures combining multiple mechanisms.

Key findings reveal that successful university-led innovation ecosystems in SSA are characterised by multi-stakeholder collaboration, formalised technology transfer structures, dedicated innovation infrastructure and adaptive governance responsive to local contexts. However, persistent challenges include limited funding, weak intellectual property frameworks, inadequate policy support, insufficient industry engagement, and capacity constraints.

Technology transfer mechanisms in SSA include formal TTOs, licencing and patenting systems, spin-off company creation, collaborative research, and informal consulting arrangements, with varying levels of formalisation and effectiveness across contexts. University-industry linkages range from informal consultancy to structured partnerships involving collaborative research centres, industrial chairs, and work-integrated learning programs.

Innovation infrastructure, including science and technology parks, business incubators, accelerators, and innovation hubs, provides essential physical and organisational support for innovation activities, although development remains uneven across the region. Emerging opportunities include digital transformation, regional collaboration networks and sector-specific innovation ecosystems.

6.2. Policy Recommendations

Based on the synthesis of evidence, this review offers the following policy recommendations for strengthening university-led innovation ecosystems in SSA:

i. Establish National Knowledge Transfer Frameworks: Governments should develop comprehensive national policies addressing IP ownership, technology transfer mechanisms, benefit sharing, and coordination structures, learning from South Africa's experience while adapting to local contexts (Zaidi and Musoke, 2020; Osayande *et al.*, 2025).
ii. Increase Research Commercialisation Funding: Dedicated funding mechanisms for technology transfer operations, proof-of-concept development, and startup seed funding are essential to overcome resource constraints (Bronstein and Bissett, 2021; Sagwa *et al.*, 2024; Osayande *et al.*, 2025).
iii. Strengthen Intellectual Property Protection: Investments in IP infrastructure, expertise development, and enforcement mechanisms will enhance technology transfer and commercialisation outcomes (Uctu and Essop, 2020; Zaidi and Musoke, 2020; Osayande *et al.*, 2025).
iv. Foster University-Industry Partnerships: Governments and universities should implement programs and incentives to encourage industry engagement including collaborative research funding, tax incentives for industry R&D partnerships, and recognition of industry engagement in academic promotion (Mensah and Gordon, 2020; Hailu, 2024; Sangwa *et al.*, 2025).
v. Build Institutional Capacity: Sustained investments in training, mentorship, and expertise development for technology transfer, IP management, business development, and innovation ecosystem coordination are critical (Bronstein and Bissett, 2021; Osayande *et al.*, 2025; Mpanju and Pistoriusf, 2026)
vi. Develop Innovation Infrastructure: Strategic investments in science parks, incubators, accelerators, and innovation hubs should be prioritised, with attention to sustainable business models and integration with academic missions (Lyken-Segosebe *et al.*, 2020; Nyemba, Mbohwa and Carter, 2021a; Ujam, 2024).
vii. Promote Regional Collaboration: Regional networks and shared services can enable economies of scale and resource sharing, particularly benefiting smaller institutions (Khumalo and Du Plessis, 2024; Shao *et al.*, 2025).
viii. Leverage Digital Technologies: Digital platforms and AI-driven systems offer opportunities to overcome traditional barriers and enhance innovation ecosystem effectiveness (Letsebe, Ebewo and Nesamvuni, 2024; Osayande *et al.*, 2025).
ix. Adapt International Models: While learning from international best practices, SSA universities should adapt governance models to local contexts rather than directly importing approaches from developed countries (Gachie and Govender, 2017; Kruger and Steyn, 2020; Osayande *et al.*, 2025).
x. Monitor and Evaluate Impact: Systematic monitoring and evaluation of innovation ecosystem initiatives enable learning, adaptation, and evidence-based policy development (Bafon *et al.*, 2024).

6.3 Future Research Directions

This review identifies several important directions for future research on university-led innovation ecosystems in SSA:

i. Longitudinal Impact Studies: Long-term studies examining the economic, social, and developmental impacts of different governance models and innovation ecosystem initiatives are needed to understand what works and why (Payumo, Lemgo and Maredia, 2017).
ii. Comparative Analysis: Systematic comparisons across SSA countries and with other developing regions would illuminate how contextual factors influence governance effectiveness and identify transferable lessons (Ayah *et al.*, 2020).
iii. Implementation Research: Detailed studies of implementation processes, challenges, and success factors for specific governance mechanisms and infrastructure initiatives would provide practical guidance for practitioners (Lyken-Segosebe *et al.*, 2020; Bafon *et al.*, 2024).
iv. Stakeholder Perspectives: Research examining perspectives of diverse stakeholders including industry partners, government officials, entrepreneurs, and community members would enrich understanding of innovation ecosystem dynamics (Mensah and Gordon, 2020; Sangwa *et al.*, 2025).
v. Informal Mechanisms: Greater attention to informal technology transfer and knowledge exchange mechanisms would provide a more complete picture of how innovation occurs in SSA context (Mensah and Gordon, 2020; Sangwa *et al.*, 2025).

vi. Digital Innovation: Research on digital transformation of innovation ecosystem governance, including AI-driven frameworks and online platforms, would inform emerging practices (Letsebe, Ebewo and Nesamvuni, 2024; Osayande *et al.*, 2025).
vii. Social Innovation: Studies examining governance of social innovation and community-engaged research would address important dimensions of university impact beyond commercial outcomes (Gachie and Govender, 2017; Kruger and Steyn, 2020).
viii. Regional Collaboration: Research on regional innovation networks and cross-border collaboration mechanisms would support development of effective regional approaches (Khumalo and Du Plessis, 2024; Shao *et al.*, 2025).
ix. Capacity Development: Studies examining effective approaches to building innovation ecosystem capacity, including training programs, mentorship, and organisational development, would inform capacity-building initiatives (Bronstein and Bissett, 2021; Mpanju and Pistoriusf, 2026).
x. Policy Analysis: Systematic analysis of policy frameworks, implementation processes, and policy impacts would strengthen evidence-based policy development (Uctu and Essop, 2020; Zaidi and Musoke, 2020).

These research directions would advance both scholarly understanding and practical effectiveness of university-led innovation ecosystems in SSA, contributing to innovation-driven development across the region.

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