Standards-related Regional Innovation and International Cooperation
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REVIEW

Toward a Harmonized Future: Regional Innovation Systems, Global Standards, and the Path to Sustainable Development

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ABSTRACT

Fragmentation between Regional Innovation Systems (RIS) and Global Standardization Frameworks (GSF) presents a critical barrier to advancing sustainable development, technological diffusion, and coherent international policy coordination. This paper investigates how harmonization between RIS and GSF can catalyze innovation while also addressing the risks of lock-in, inequity, and fragmentation. Drawing on a conceptual and narrative review, we develop a conceptual framework that positions standardization as both an enabler and constraint of innovation. Our analysis is guided by three dimensions: the tension between localized innovation and global uniformity, the role of standards as mediating mechanisms for diffusion and legitimacy, and the challenges of polycentric governance and path dependency. Through critical synthesis, the paper argues that standardization reduces uncertainty, scales markets, and facilitates knowledge transfer, but also risks privileging dominant actors and excluding local contexts. Polycentric governance emerges as the key solution, offering a pathway to reconcile regional diversity with the universality of global rules. The primary contribution is the proposal of a novel Comparative Framework and Key Performance Indicators (KPIs) designed to systematically evaluate harmonization outcomes, addressing the critical gap in current innovation policy literature. We conclude that by reframing harmonization as a dynamic, iterative process rather than a fixed institutional goal, the paper highlights pathways for aligning innovation systems with global sustainability imperatives. The findings contribute to theory-building on innovation governance and provide insights for policy frameworks navigating technological and environmental transitions.

Keywords: Regional Innovation Systems; Global Standardization; Sustainable Development; Polycentric Governance; Knowledge Transfer; Technological Diffusion; Policy Coordination; Innovation Pathways

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ARTICLE INFO
Received: 20 May 2025 | Revised: 7 July 2025 | Accepted: 15 July 2025 | Published Online: 22 July 2025
DOI: https://doi.org/10.63385/sriic.v1i2.333

CITATION
Jacob, D.E., Jacob, I.D., 2025. Toward a Harmonized Future: Regional Innovation Systems, Global Standards, and the Path to Sustainable Development. Standards-related Regional Innovation and International Cooperation. 1(2): 14–33. DOI: https://doi.org/10.63385/sriic.v1i2.333

1. Introduction

The contemporary landscape of technological advancement and global sustainability is marked by a fundamental tension between the localized dynamics of Regional Innovation Systems (RIS) and the overarching structures of Global Standardization Frameworks (GSF). RIS are widely recognized as engines of place-based development, fostering innovation through networks of firms, research institutions, governments, and other stakeholders that operate within specific territorial contexts[1,2]. These systems generate unique knowledge, adapt technologies to local needs, and reinforce competitive advantages. Yet, as technologies increasingly transcend borders and global markets demand interoperability, they confront GSF regimes that seek to harmonize rules, processes, and benchmarks across industries and countries[3]. This fragmentation, where innovation remains largely regional while standards demand global alignment, presents both opportunities and challenges for achieving sustainable development and coherent international policy coordination.

The problem becomes more pronounced in sectors central to sustainability, such as renewable energy, digital infrastructure, and biotechnology. For instance, while European regional clusters may pioneer innovations in green hydrogen or smart grid technologies, their scalability and adoption hinge on adherence to GSF that ensures interoperability and trust across markets[4]. Without alignment, regional advancements risk remaining siloed, leading to inefficiencies, duplication of efforts, and barriers to international diffusion. Conversely, excessive imposition of Global Standards (GS) without sensitivity to local innovation contexts may suppress experimentation and stifle creativity[5]. Thus, fragmentation between RIS and standardization bodies not only delays technological advancement but also undermines sustainability agendas that require coordinated global responses.

The significance of harmonization lies in its potential to bridge this divide by creating feedback loops between regional innovation processes and global governance structures. Sustainable development, as articulated in the United Nations Sustainable Development Goals (SDGs), depends on technologies and practices that are both locally adaptive and globally scalable[6]. RIS are critical for tailoring innovations to specific socio-economic and ecological contexts, while standardization ensures that these innovations can circulate beyond regional boundaries and contribute to systemic transformation[7]. Harmonization, therefore, is not merely a technical issue but a strategic imperative for aligning diverse knowledge systems, ensuring equitable access to innovation benefits, and fostering resilience in the face of global crises such as climate change and pandemics.

Technological advancement further underscores the urgency of harmonization. Emerging technologies like artificial intelligence, biotechnology, and renewable energy infrastructures evolve at unprecedented speed, often outpacing regulatory and standardization processes[8]. When RIS generate innovations without adequate pathways to global standardization, diffusion becomes fragmented, leading to "islands of innovation" that lack international impact[9]. On the other hand, premature or rigid standardization risks locking in suboptimal technologies, thereby constraining innovation trajectories. Balancing the flexibility of RIS with the stability of GS requires deliberate mechanisms that allow for mutual adjustment, a dynamic co-evolution rather than a one-way imposition of global norms.

Equally, the policy dimension highlights why harmonization matters. Policymakers at regional, national, and international levels grapple with reconciling innovation policies designed for local competitiveness with regulatory frameworks aimed at international alignment[10]. A lack of coordination leads to fragmented governance, where innovation incentives in one region clash with compliance requirements in another, creating uncertainty for firms and investors. By harmonizing RIS with GS, policymakers can reduce transaction costs, enhance innovation diffusion, and build coherent pathways that align technological progress with sustainability imperatives[11]. In essence, harmonization functions as a cornerstone for ensuring that innovation contributes not just to local growth but also to collective global goals.

This paper seeks to address these issues by synthesizing existing literature on the interplay between RIS and GSF, critically evaluating where gaps and tensions persist, and proposing a conceptual pathway for harmonization. The objective is not only to map the state of knowledge but also to contribute to theory-building by offering a framework that situates RIS within the global governance of innovation and sustainability. Current research often analyzes RIS and GSF in isolation, overlooking the crucial, dynamic interaction between localized innovation and global rule-making. A deeper

understanding of this RIS–GSF nexus is critical because the success of global sustainability efforts from renewable energy deployment to equitable technology access depends on aligning the speed and diversity of regional experimentation with the stability and legitimacy provided by global standards. The central purpose of this study is to move beyond mere descriptive analysis of RIS-GSF conflicts and develop a prescriptive, evaluative framework. The gap this model fills is the absence of a comprehensive, measurable system for aligning localized RIS-driven innovations with the demands of GSFs, particularly concerning the achievement of the SDGs[2]. By doing so, the paper aims to highlight actionable insights for scholars, policymakers, and practitioners seeking to navigate the complexities of innovation–standardization dynamics in the 21st century. Methodologically, this paper employs a conceptual and narrative review approach, synthesizing scholarly works across innovation studies, global governance, and standardization[3]. The review process, detailed in Section 2, systematically maps the core tensions and synergies between RIS and GSF, which then informs the development of the proposed conceptual framework in Section 5.

The guiding research questions framing this exploration are as follows:

1. How do regional innovation systems (RIS) contribute to technological advancement and sustainability within their localized contexts?
2. In what ways do global standardization frameworks (GSF) facilitate or constrain the diffusion of innovations across regions and markets?
3. What mechanisms, governance models, or policy instruments can bridge RIS and GS to foster harmonization?
4. How can harmonization advance both technological innovation and sustainable development while maintaining sensitivity to regional diversity?

The remainder of this paper is structured as follows: Section 2 outlines the research approach and conceptual synthesis method. Section 3 provides the conceptual foundations and a review of the relevant literature on RIS and GSF. Section 4 presents a comparative analysis of their institutional structures and policy dynamics. Section 5 introduces the comparative framework and Key Performance Indicators (KPIs) for evaluating harmonization. Finally, Section 6 provides the conclusions, outlines the study's limitations, and suggests avenues for future research.

2. Research Approach and Conceptual Synthesis

The present study utilizes a conceptual and narrative review approach, based on a broad desktop literature search[12]. This methodology is employed to systematically synthesize a fragmented body of knowledge across multiple disciplines, namely, innovation studies, global governance, and standardization, to construct a new theoretical framework. The literature search and selection process involved a targeted, non-systematic desktop search of established scholarly works (articles, book chapters, and authoritative policy reports) published primarily since 2000. The focus was on identifying key publications addressing the core conceptual overlap between Regional Innovation Systems (RIS) and Global Standardization Frameworks (GSF), as well as related concepts such as polycentric governance, institutional asymmetry, and the Sustainable Development Goals (SDGs). To ensure quality and conceptual relevance, the general principles guiding source inclusion were:

1. **Conceptual Relevance:** Inclusion was limited to works explicitly addressing the linkages, tensions, or governance between RIS/regional innovation and global/transnational standardization.
2. **Scholarly Rigor:** Priority was given to peer-reviewed, high-impact publications (journal articles and academic books) that provide foundational definitions, highlight core tensions, and propose governance solutions at the multi-scalar interface of localized innovation and global standard-setting.
3. **Timeliness:** Sources were primarily selected from publications since 2000 to capture contemporary dynamics of globalization, digital transition, and sustainability standard-setting.
4. **Authoritative Policy Reports:** Selected reports from international bodies (e.g., OECD, UN) were included if they provided empirical data or policy insights on the innovation–standardization interface.

The goal of this narrative review was to achieve critical commentary and conceptual coherence rather than exhaustive, systematic data extraction[13]. The selection pri-

oritized high-impact works that provide foundational definitions, highlight core tensions, and propose governance solutions at the multi-scalar interface of localized innovation and global standard-setting. The thematic synthesis of this corpus of literature informed the subsequent critical analysis and the development of the conceptual harmonization framework presented in Section 5.

3. Conceptual Foundations and Literature Review

3.1. Regional Innovation Systems (RIS)

Regional Innovation Systems (RIS) are conceptualized as territorially bounded networks of firms, institutions, and knowledge-producing organizations that foster collective learning and innovation [1]. They emerged as a critical framework to understand how regions act as engines of knowledge production and industrial competitiveness. These systems are typically nested within National Innovation Systems (NIS), which provide a broader institutional and political context, although the focus remains on the regional level. Unlike NIS, RIS emphasizes the role of proximity, localized spillovers, and institutional thickness in driving innovation dynamics [14]. Both RIS and the overarching NIS are increasingly subjected to the external pressure and influence of Global Standardization Frameworks (GSF), necessitating a multi-scalar understanding of innovation governance. Universities, research centers, clusters of small- and medium-sized enterprises (SMEs), and local governments form the backbone of these systems, generating tacit knowledge that is embedded in local social and institutional relations.

RIS excel in fostering path-dependent innovations that often reflect regional histories, specializations, and industrial legacies. For example, Silicon Valley epitomizes a knowledge-intensive RIS where venture capital, universities, and entrepreneurial culture interact dynamically [15]. In contrast, green innovation clusters in Nordic regions illustrate how RIS can align technological advancement with sustainability by emphasizing renewable energy transitions [16]. However, RIS often face fragmentation. Localized experimentation sometimes lacks the mechanisms for scaling innovations to broader markets, limiting global impact. However, the traditional RIS concept is often criticized for being too static and paying insufficient attention to these global linkages. This problem becomes pronounced in the absence of harmonized standards, where region-specific solutions fail to achieve interoperability or international legitimacy. The framework proposed in this paper directly addresses this critique by analyzing how RIS co-evolve with and are constrained by GSFs. **Table 1** provides a comparative overview of the core distinctions between RIS and GSF.

Table 1. Comparative Characteristics of Regional Innovation Systems (RIS) and Global Standardization Frameworks (GSF).

Dimension	Regional Innovation Systems (RIS)	Global Standardization Frameworks (GSF)
Primary Focus	Localized knowledge creation, technology diffusion, clusters	Cross-national rules, norms, technical specifications
Institutional Drivers	Regional governments, universities, SMEs, clusters	International Organization for Standardization (ISO), International Telecommunication Union (ITU), and World Trade Organization (WTO), and multinational corporations
Scope	Sub-national, geographically bounded regions (e.g., Silicon Valley, EU clusters).	Global, often sector-specific (e.g., International Organization for Standardization (ISO) Technical Committees).
Governance Style	Networked, informal, polycentric (internal).	Formal, hierarchical, often public-private partnership (PPP).
Temporal Orientation	Short-to-medium term, adaptive	Long-term stability and predictability
Flexibility	High, tailored to context	Low-to-moderate, emphasizing uniformity
Sustainability Role	Place-based ecological and socio-economic development	Global sustainability metrics and carbon neutrality standards

Table 1. *Cont.*

Dimension	Regional Innovation Systems (RIS)	Global Standardization Frameworks (GSF)
Knowledge Flows	Informal, tacit, path-dependent	Formalized, codified, globally diffused
Challenges	Risk of fragmentation, lack of scaling	Risk of rigidity, slow adaptation to emerging technologies

3.2. Global Standardization Frameworks (GSF)

Global Standardization Frameworks (GSF) are the institutionalized mechanisms through which norms, technical specifications, and rules are codified to govern international trade, interoperability, and market stability [17]. Organizations such as the ISO, International Telecommunication Union (ITU), and the World Trade Organization (WTO) play critical roles in this domain. The GSF operates on a scale far removed from localized RIS dynamics, often reflecting a consensus among powerful nations and multinational corporations. These frameworks ensure that technological systems are interoperable across regions, products meet safety and environmental requirements, and international commerce flows with reduced transaction costs [5]. Standardization is not merely technical but also deeply political, reflecting power asymmetries in global governance. For example, ISO standards often reflect consensus shaped by technologically advanced countries, creating challenges for emerging economies seeking to align local innovations with global rules [18]. Similarly, the WTO's Agreement on Technical Barriers to Trade highlights the tension between global uniformity and the sovereignty of nations to regulate according to local needs [19]. The historical co-evolution of RIS and GSF demonstrates that standardization has often lagged behind innovation, catching up only after technologies stabilize. **Table 2** traces this co-evolution, showing how successive waves of industrial, post-war, globalization, and green transitions have shaped both innovation systems and standardization paradigms.

Table 2. Historical Evolution of RIS and Standardization Paradigms.

Period/Wave	RIS Characteristics	GS Characteristics	Example
Industrial Revolution (18th–19th C.)	Early regional clusters, mechanization hubs	Early measurement standards (weights, measures)	Metric system
Post-War Era (1945–1970s)	State-led innovation, industrial policy	Emergence of ISO, General Agreement on Tariffs and Trade (GATT) technical standards	ISO 9000
Globalization Era (1980s–2000s)	Knowledge-based RIS, triple helix models	ICT and trade-related standards	ITU telecom standards
Digital & Green Transition (2000s–present)	Smart specialization, green innovation	Sustainability, Artificial Intelligence (AI) ethics, climate standards	EU Green Deal, ISO climate standards

3.3. Linking Innovation and Standards

The relationship between RIS and GSF is characterized by both tension and synergy. RIS thrives on diversity, experimentation, and adaptability, fostering unique technological solutions tailored to local contexts [2]. In contrast, GSF prioritizes uniformity, interoperability, and predictability, which are essential for international trade, global policy alignment, and knowledge transfer [3]. This divergence often results in conflicts when localized innovations encounter rigid global requirements. For example, the adoption of renewable energy technologies frequently faces delays due to varying international certification standards that may not align with local experimentation [20]. Yet, this friction also creates opportunities for transformative scaling: successful regional innovations can influence the development of new international norms, while GS can provide the legitimacy and diffusion pathways that accelerate technological uptake [5]. As illustrated in **Figure 1**, the overlap zone between RIS and GSF demonstrates this dual dynamic, a situation where local innovations gain global reach and where standards reinforce regional capabilities. Ultimately, harmonization lies in navigating this intersection, ensuring that global frameworks remain responsive to regional specificities without stifling creativity.

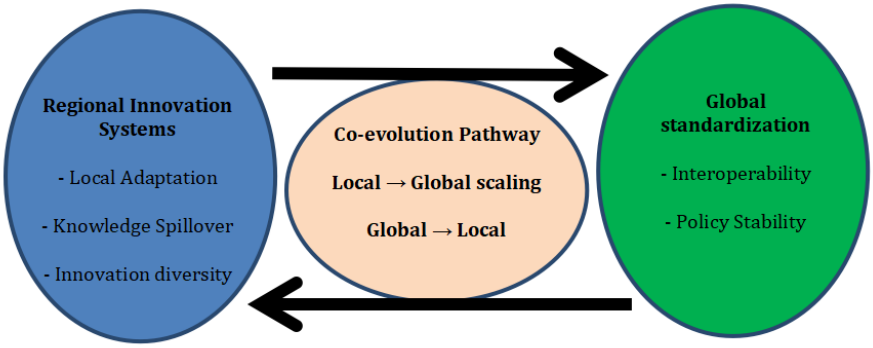

Figure 1. Interactions Between Regional Innovation Systems and Global Standardization Frameworks (GSF).

3.4. Thematic Integration between Innovation, Standards, and Sustainability

Sustainability offers a critical thematic bridge between innovation and standardization. While innovation generates the technological solutions necessary for energy transitions, resource efficiency, and climate resilience, standards provide the governance instruments that ensure these innovations are safe, interoperable, and widely adoptable [21]. However, fragmentation remains a pressing challenge: RIS often prioritizes context-specific sustainability needs, such as water management in arid regions or clean cookstove technologies in rural Africa, while global frameworks seek universal benchmarks that may overlook local constraints [22,23]. The challenge, therefore, is aligning local innovation dynamics with global sustainability imperatives without reducing them to a one-size-fits-all model. The information in **Table 3** highlights how tensions such as short-term commercial goals versus long-term environmental outcomes can be transformed into complementarities through hybrid governance mechanisms. Successful cases, such as the incorporation of Nordic eco-innovation practices into EU environmental directives, demonstrate how localized sustainability models can influence broader regulatory landscapes [24]. The key lies in fostering iterative feedback loops: regional innovations must continuously inform the evolution of GS, while standards must maintain flexibility to integrate emergent sustainability practices. Such integration is central to steering both innovation and governance toward sustainable global futures.

Table 3. Tensions and Complementarities between RIS and GSF.

Issue Area	Tension (Fragmentation)	Complementarity (Harmonization Potential)
Technology Development	RIS pushes rapid, diverse experimentation; GSF requires stability	Standards allow RIS innovations to scale globally
Sustainability Goals	Regional ecological priorities differ	Global frameworks embed sustainability benchmarks
Policy Coordination	Local autonomy vs. global compliance	Multi-level governance enables alignment
Knowledge Governance	Tacit learning vs. codified rules	Standards codify local innovations for diffusion
Adaptability	RIS are highly adaptive, context-specific	Standards provide the predictability, market trust

3.5. Governance and Pathways toward Harmonization

Governance is central to reconciling RIS diversity with the universality of GSF. Traditional top-down approaches, often dominated by international bodies such as ISO and WTO, risk marginalizing regional actors whose innovations do not conform to predefined Global Standards (GS). A central concern is the theme of power and dominance, where standardization often reflects the economic interests and technological trajectories of developed countries and powerful multinational corporations [25]. In contrast, multilevel governance models propose a more distributed architecture, where multiple centers of authority, including governments, firms, standardization bodies, and regional networks, jointly

shape rules and practices[26]. **Figure 2** conceptualizes RIS–GSF interaction as a dynamic system, where knowledge and standards circulate across multiple levels. This is further expanded in **Figure 3**, which illustrates how polycentric governance fosters complementarity between local experimentation and global codification. Such arrangements enhance legitimacy by ensuring inclusivity, adaptability, and resilience in decision-making[27]. However, for polycentric governance to genuinely overcome these power asymmetries, rather than merely legitimizing them, it must actively empower developing regions and local RIS actors in the standard-setting process. For example, the governance of digital standards increasingly involves collaborations between multinational corporations, regional regulators, and international organizations to address cybersecurity and sustainability simultaneously[28]. By embedding flexibility and multi-level negotiation into standard-setting, polycentric governance mitigates risks of regulatory capture and rigidity. Harmonization, therefore, should not imply uniformity, but rather coordinated plurality, where diverse innovation pathways are integrated within globally coherent frameworks for sustainability and technological advancement.

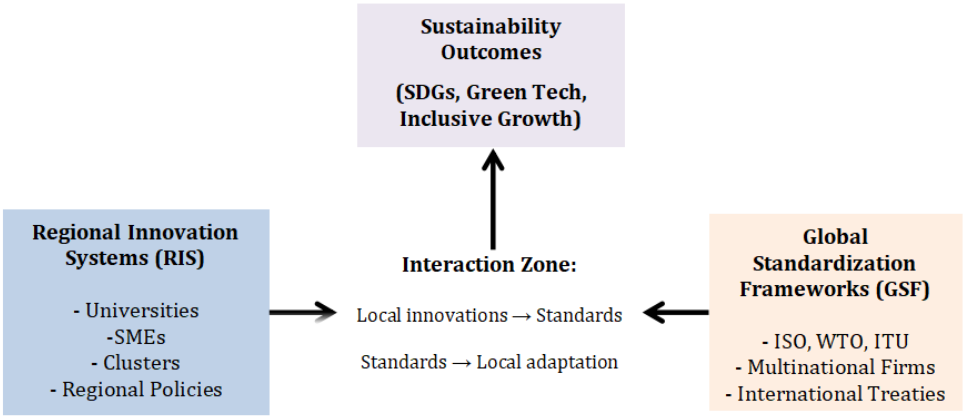

Figure 2. Conceptual Framework of RIS–GSF Interaction for Sustainable Development.

Building on this, **Figure 3** outlines a polycentric governance architecture. At the bottom are regional actors (SMEs, governments, universities), in the middle are bridging institutions (European Union (EU), Organisation for Economic Co-operation and Development (OECD), United Nations (UN), Public–Private Partnerships (PPPs)), and at the top are global standardization bodies (ISO, WTO, ITU). Arrows illustrate the feedback loops between local innovation and GS. Thus, the concept reveals that RIS and GSF are not isolated spheres but mutually constitutive. RIS provides the diversity and adaptability needed for rapid technological and sustainability transitions, while GSF provides the stability and predictability necessary for international diffusion. Consequently, harmonization requires polycentric governance that allows local diversity to flourish while embedding sustainability into global norms. This dual dynamic forms the foundation for advancing sustainable development through innovation-standardization linkages.

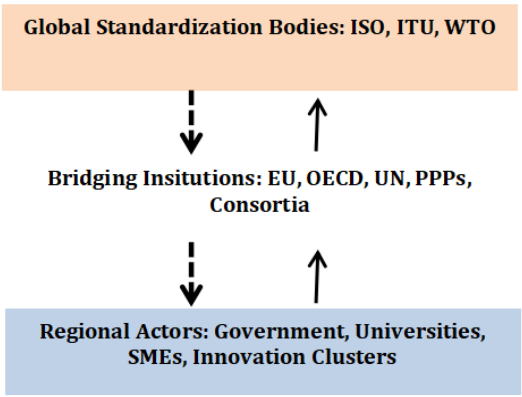

Figure 3. Polycentric Governance Model for RIS–GSF Integration.

4. Comparative Analysis of RIS and Global Standardization Frameworks

The integration of RIS with GSF presents both opportunities and challenges in advancing technological develop-

ment, ensuring sustainability, and promoting policy coherence. RIS are context-specific networks that foster innovation through localized collaboration, while global standardization frameworks (GSF) provide internationally recognized rules, guidelines, and metrics that enable cross-border compatibility. An exploration of the comparative dimensions between these two paradigms, analyzing their institutional structures, policy approaches, and practical interactions in innovation ecosystems, is provided below. The aim is to critically evaluate complementarities and tensions, while identifying pathways for harmonization

4.1. Institutional and Governance Structures of RIS and GSF

RIS and GSF are built upon fundamentally different governance logics. RIS typically operate through decentralized, multi-level networks involving universities, firms, regional governments, and innovation clusters. Their governance is adaptive and strongly rooted in the socio-economic and cultural conditions of specific regions [1,29]. For instance, a European RIS may be heavily influenced by the European Union's cohesion policies, while an Asian RIS could be shaped by state-led industrial policy. These localized institutional variations make RIS highly responsive to regional needs but can limit its scalability across borders. By contrast, global standardization frameworks (GSF), such as those established by the ISO, the International Electrotechnical Commission (IEC), and industry consortia like the Institute of Electrical and Electronics Engineers (IEEE), emphasize universality and uniformity. Their governance structures are highly formalized, relying on expert committees, multi-stakeholder consultations, and consensus-building across national boundaries [7]. These structures seek to minimize fragmentation in global trade and technological systems by creating universally applicable technical standards.

A key point of divergence lies in accountability mechanisms. RIS accountability is oriented toward regional stakeholders, reflecting democratic or socio-economic priorities of a locality. GSF, on the other hand, demands neutrality and technical rigor, with accountability to transnational industry stakeholders and governments. This divergence creates governance asymmetries: what works regionally may conflict with global rules, and vice versa [30]. For instance, a RIS promoting indigenous renewable energy technologies may face barriers when interfacing with globally standardized technical specifications designed with Western or Asian markets in mind. Yet, synergies do exist. Both RIS and GSF share the objective of fostering innovation diffusion and reducing systemic inefficiencies. The European Union's smart specialization strategy, for example, demonstrates how regional innovation priorities can be aligned with international standards in renewable energy and digital infrastructure [31]. Under programs like Horizon 2020 and its successor, firms in RIS are incentivized with funding only if their innovative products meet emerging European or international technical standards, thus ensuring that regional experimentation is aligned with global market requirements from the outset. This mechanism offers a concrete example of successful integration, though a full case study is beyond the scope of this review. Moreover, the rise of transnational Public-Private Partnerships (PPPs) suggests a hybrid model where RIS actors contribute localized knowledge into global standardization processes [32]. **Table 4** provides a comparative overview of governance structures in RIS and GSF.

Table 4. Comparative Governance Features of RIS and GSF.

Feature	RIS	GSF
Governance level	Decentralized, multi-level	Centralized, transnational
Stakeholder orientation	Regional stakeholders (firms, universities, gov.)	Industry, governments, and international experts
Accountability mechanisms	Regional policy and socio-economic needs	Neutrality, technical rigor, consensus
Adaptability	High, context-specific	Moderate, seeks universal applicability
Innovation diffusion	Local–regional	Cross-border/global

4.2. Policy Mechanisms and Innovation Dynamics

RIS and GSF diverge in their policy instruments and innovation incentives, reflecting their differing purposes and constituencies. RIS often rely on regionally tailored policy mixes, such as subsidies for local SMEs, tax incentives for research and development (R&D), and infrastructural investments in clusters. These policies prioritize knowledge

spillovers, local capacity building, and territorial competitiveness[2]. For example, Finland's regional innovation policy emphasizes supporting SMEs through collaborative networks between local universities and industries. Such mechanisms foster embeddedness but can inadvertently create "innovation silos," limiting cross-border scalability. GSF, by contrast, embeds innovation within codified technical norms, certification processes, and conformity assessments. Standards such as ISO 14001 for environmental management or ISO/IEC 27001 for information security serve as global benchmarks that firms must meet to remain competitive in international markets[33]. These standards not only assure of quality and safety but also stimulate innovation by setting performance thresholds that drive firms toward efficiency and technological upgrading.

However, the central issue lies in innovation speed and flexibility. RIS, due to their regional adaptability, can rapidly test and implement innovations. In contrast, global standardization frameworks (GSF) often involve long deliberative processes to achieve consensus, slowing responsiveness to fast-evolving technologies such as AI, blockchain, or synthetic biology[34]. This mismatch creates tension: RIS thrives on flexibility, while standards thrive on stability. Moreover, complementarities are evident. RIS can serve as experimental laboratories, piloting innovations that, once validated, can be codified into GS. The 5G standardization process demonstrates this synergy: regional pilots in South Korea, the U.S., and Europe provided empirical data feeding into the 3rd Generation Partnership Project (3GPP) that established global telecom standards[35]. In this way, RIS generates diversity, while GS provides convergence. **Table 5** highlights the contrasting and complementary policy mechanisms shaping innovation dynamics.

Table 5. Policy Mechanisms in RIS and Global Standardization Frameworks.

Dimension	RIS	GSF
Policy Focus	Regional competitiveness, SME growth, place-based innovation	Trade facilitation, interoperability, and global market access
Instruments	R&D subsidies, tax incentives, cluster development, local partnerships	Technical standards, certifications, conformity testing, ISO/IEC rules
Speed of Uptake	Rapid, flexible, adaptive to local experimentation	Slower, consensus-driven, dependent on international negotiations
Innovation Incentives	Knowledge spillovers, localized learning, entrepreneurial dynamism	Compliance, efficiency gains, credibility in global markets
Governance Mode	Decentralized, regionally adaptive, shaped by path dependency	Centralized or polycentric, led by states and international bodies
Stakeholder Roles	SMEs, universities, local governments, and civil society are actively engaged	Multinational corporations and technical committees dominate
Equity Orientation	Local job creation, regional sustainability, inclusive development	Risk of marginalizing weaker economies, inclusion varies by leverage
Risk Approach	Experimentation tolerance, rapid feedback, protection for niche innovation	Stability and predictability prioritized, but prone to technological lock-in
Knowledge Flows	Tacit, informal, and trust-based exchanges within regional networks	Codified, formalized knowledge embedded in GS
Sustainability Framing	Tailored eco-innovation aligned with regional ecological challenges	Universal benchmarks for emissions, energy efficiency, and reporting

4.3. Integration and Interoperability Challenges

Despite their potential synergies, RIS and global standardization frameworks (GSF) face significant barriers to integration. These challenges include misaligned priorities, institutional asymmetries, and resource disparities (**Table 6**). First, priority misalignment occurs when regional innovation agendas emphasize socio-economic goals (e.g., local job creation, cultural sustainability), while GS prioritizes tech-

nical interoperability and market efficiency. For example, African RIS initiatives in renewable off-grid energy often design technologies for affordability and local adaptability, which may not immediately align with global certification requirements [36].

Second, institutional asymmetries manifest in uneven capacities. Advanced RIS in Europe or East Asia often contribute directly to global standard-setting processes through representation in ISO or IEC committees, whereas RIS in the Global South may lack the financial and technical capacity to participate effectively [37]. This exclusion risks reinforcing inequalities, with standards reflecting the interests of dominant economies. Third, resource disparities hinder interoperability. Developing regions frequently struggle to meet the technical and financial costs of compliance with GS. The World Trade Organization's Technical Barriers to Trade (TBT) Agreement recognizes this issue, noting that GS can act as a hidden trade barrier when local firms lack resources to adapt [38]. Nevertheless, successful integration is possible. For instance, the EU's Horizon 2020 projects have demonstrated how regional innovation pilots can be harmonized with international standards in fields like smart grids and digital health [39]. Similarly, voluntary sustainability standards in agriculture, such as Fairtrade, illustrate how local RIS adaptations can gain global legitimacy when aligned with internationally recognized principles [40].

Table 6. Integration and Interoperability Challenges.

Challenge	RIS Perspective	GS Perspective	Potential Solution
Priority Misalignment	Focus on socio-economic development and regional needs	Focus on technical interoperability and global efficiency	Dialogue platforms bridging local–global priorities
Institutional Asymmetries	Limited voice in international decision-making forums	Dominance of developed-country institutions	Inclusive governance, representation reforms, capacity-building
Resource Disparities	Financial and technical constraints for SMEs and regions	High compliance and certification costs	Subsidies, staged or differential implementation pathways
Knowledge Gaps	Reliance on tacit and context-specific know-how	Preference for codified, formalized knowledge	Knowledge-sharing networks, translation into local contexts
Innovation Timing	Rapid, adaptive experimentation at local levels	Slow, consensus-driven global processes	Flexible standards, iterative updates, regional pilot integration
Equity Concerns	Need for inclusive development and local employment	Risk of reinforcing global hierarchies and exclusion	Social safeguards, equity-oriented standard design

The analysis in this section reveals persistent institutional, policy, and interoperability challenges arising from the inherent differences between localized RIS and universal GSFs. While Section 4 provided a critical diagnosis of these tensions, the logical next step is to prescribe solutions and provide tools for evaluation. Section 5 moves from description to prescription by developing a conceptual framework and identifying Key Performance Indicators (KPIs) designed to systematically evaluate the performance, impact, and effectiveness of policy interventions aimed at bridging the specific fragmentation and asymmetries identified in this comparative analysis, thus ensuring a strong logical connection between the two sections.

5. Comparative Framework and Key Performance Indicators (KPIs)

Comparative frameworks and Key Performance Indicators (KPIs) are essential for moving beyond qualitative analysis to provide systematic, measurable tools for evaluating the often-intangible interactions between RIS and GSF. While Section 4 explored institutional, policy, and interoperability issues, this section builds an evaluative model for assessing synergies, trade-offs, and performance outcomes. The proposed framework is grounded in the principles of polycentric governance and is designed to be methodologically rigorous and replicable, allowing policymakers to track

progress and adjust strategies. The adjoining subsections outline the conceptual comparative framework, identify specific KPIs, and establish methodological approaches to measuring effectiveness.

5.1. Conceptual Foundations of the Comparative Framework

The comparative framework is built on the recognition that RIS and global standardization frameworks (GSF) operate under distinct logics but intersect in ways that shape innovation performance, sustainability outcomes, and global competitiveness. RIS are embedded in regional socio-economic contexts, focusing on localized innovation spillovers, capacity building, and cluster development [2]. GSF, on the other hand, emphasizes interoperability, quality assurance, and international trade facilitation [3]. Any comparative framework must therefore integrate both localized adaptability and global uniformity (**Table 7**). The conceptual foundation draws on three strands of literature. First, systems of innovation theory highlights how knowledge flows and networks drive innovation within spatial boundaries [9]. Second, institutional theory emphasizes how governance structures, norms, and rules shape innovation processes [41]. Third, standardization economics provides insights into the role of technical norms in reducing transaction costs, mitigating uncertainty, and diffusing innovation [5]. By synthesizing these perspectives, the framework establishes multidimensional axes for comparison: governance, policy mechanisms, innovation outputs, sustainability integration, and global competitiveness. A central element of the framework is the interaction continuum between RIS and GS, ranging from complementarity (e.g., RIS pilots feeding GS) to conflict (e.g., local practices excluded by rigid GS). The framework thus provides both a diagnostic and prescriptive lens, thus, diagnosing where synergies or tensions exist and prescribing mechanisms for alignment. The conceptual framework, therefore, does not assume hierarchy but seeks to balance regional diversity with global convergence. Its foundations highlight that effective integration requires translation mechanisms like institutions and processes that bridge local innovation logics with international norms. This sets the stage for defining KPIs that can empirically measure how well such integration works in practice.

Table 7. Dimensions of the Comparative Framework.

Dimension	RIS Perspective	GSF Perspective	Comparative Implication
Governance	Decentralized, regional actors	Centralized, transnational bodies	Potential governance asymmetry
Policy mechanisms	Tailored incentives, SME support	Technical standards, conformity requirements	Policy complementarities and conflicts
Innovation outputs	Regional spillovers, cluster development	Interoperable technologies, market scalability	Scaling local innovation globally
Sustainability integration	Place-based green innovation	Global sustainability metrics (ISO 14000, SDGs)	Alignment or mismatch in sustainability goals
Competitiveness	Regional economic resilience	Global market access and credibility	Pathways to harmonization

5.2. Key Performance Indicators for Evaluating RIS and Standards Integration

KPIs serve as quantifiable measures that capture performance across multiple dimensions of RIS and global standardization. Their development must reflect both the qualitative diversity of RIS and the quantitative rigor of GS. Effective KPIs thus require balancing context-sensitive metrics with internationally comparable indicators. Key categories of KPIs include the following:

1. **Innovation Capacity:** Innovation capacity remains the bedrock of regional competitiveness and sustainability. Metrics such as R&D intensity, patent filings, and start-up growth rates highlight the ability of regions to generate novel ideas and transform them into marketable outputs. However, these indicators cannot be viewed in isolation; they must be contextualized within broader benchmarks of technological competitiveness. For example, Archibugi and Filippetti [42] argue that regional performance must be compared with international standards to ensure that local advancements contribute meaningfully to global progress. A

high start-up survival rate or increasing venture capital flows within a region, when aligned with global innovation indices, reveals both internal dynamism and global positioning.

2. **Knowledge Diffusion and Absorptive Capacity:** Knowledge diffusion is a decisive factor in ensuring that localized innovation systems do not remain isolated but instead connect with global knowledge ecosystems [43]. Indicators such as cross-regional collaboration, technology transfer agreements, and participation in global research networks capture the absorptive capacity of RIS. This dimension reflects whether regions can effectively integrate external knowledge and standards into local practices while contributing innovations outward. Participation in EU research consortia or global ICT networks, for instance, demonstrates how RIS can embed themselves in international standardization processes. The ability to absorb and adapt codified knowledge enhances resilience and aligns regional systems with global frameworks [44].
3. **Sustainability Performance:** Sustainability performance provides the normative anchor for innovation systems in the twenty-first century. Key performance indicators include carbon emission reduction, renewable energy adoption, and compliance with environmental standards such as ISO 14001 [45]. These metrics extend beyond economic outcomes, assessing whether innovation is directed toward ecological resilience and long-term sustainability. For instance, regions that achieve high penetration of renewable energy technologies or implement circular economy practices demonstrate an ability to harmonize innovation with global climate goals. By aligning regional indicators with international frameworks like the Paris Agreement, RIS can simultaneously advance local prosperity and contribute to collective planetary objectives.
4. **Market Access and Competitiveness:** Market access serves as a test of whether regional innovations transcend local confines to achieve global impact. Metrics such as the proportion of SMEs certified under international standards, export diversification, and the share of globally standardized products provide crucial insights into competitiveness [46]. Certification under ISO or any other bodies marking schemes enhances trust, enabling firms to penetrate larger markets. Export diversification, in turn, signals resilience against global shocks while enhancing integration into value chains. A region's competitiveness thus hinges not only on the novelty of its innovations but also on its capacity to adapt outputs to globally recognized standards and regulatory expectations.
5. **Institutional Inclusivity:** Institutional inclusivity ensures that harmonization processes do not privilege dominant actors but instead integrate a diversity of voices. This can be measured through the active participation of SMEs, universities, local governments, and civil society in standardization committees or consultations [47]. Inclusive participation enhances the legitimacy of standards while ensuring that local needs are not overshadowed by global corporate agendas. For example, multi-stakeholder engagement in the development of sustainability reporting standards has improved their applicability across contexts. Inclusivity thus reflects democratic governance within innovation ecosystems and promotes equitable outcomes in regional–global integration. By operationalizing these KPIs, policymakers and researchers can systematically assess not only whether RIS are innovative but also whether they are globally compatible and sustainable (**Table 8**). Importantly, KPIs should be dynamic, evolving alongside technological paradigms such as AI, biotechnology, or renewable energy systems.

Table 8. Key Performance Indicators for RIS–GS Integration.

KPI Category	Example Indicators	Comparative Significance
Innovation Capacity	R&D expenditure (% GDP), patent filings	Benchmarking regional vs. global competitiveness
Knowledge Diffusion	Cross-border collaborations, joint ventures	Gauging integration into global knowledge flows
Sustainability Performance	Carbon footprint reduction, ISO 14001 adoption	Assessing green innovation alignment
Market Access	% SMEs certified, export growth in certified goods	Measuring competitiveness through standards
Institutional Inclusivity	Stakeholder representation in global forums	Evaluating equity and participation

5.3. Methodological Approaches to Measuring Effectiveness

Measuring RIS–GS integration requires methodological pluralism, combining quantitative benchmarking with qualitative case studies (**Table 9**). A purely statistical approach risks oversimplifying regional diversity, while a purely qualitative approach may lack comparability. A mixed-methods approach ensures rigor and contextual depth[48].

Table 9. Methodological Approaches for Evaluating RIS–GS Integration.

Method Type	Tools and Techniques	Strengths	Limitations
Quantitative	Econometrics, composite indices, network analysis	Rigor, comparability, scalability	Risk of abstraction, limited contextual nuance
Qualitative	Case studies, policy analysis, interviews	Depth, context-sensitivity, institutional insight	Limited generalizability
Mixed-Methods	Triangulation of both approaches	Balanced rigor and contextual understanding	Resource-intensive

5.3.1. Quantitative Methodologies

1. **Econometric Modeling:** Econometric modeling serves as a key quantitative tool for examining the relationship between the adoption of Global Standards (GS) and innovation outcomes within RIS. For replication, researchers are advised to use publicly available and cross-regionally comparable data, such as World Bank Enterprise Surveys, OECD R&D statistics, and international certification data (e.g., ISO, WIPO). The methodological approach requires a transparent definition of dependent variables (e.g., export intensity, R&D spending, patenting) and independent variables (e.g., standard adoption rates, committee participation, standardization capacity). Regression models, for instance, can measure how ISO 9001 certification affects export performance or R&D intensity. Wilcock and Boys[49] asserted that firms adopting internationally recognized quality standards often achieve higher competitiveness due to improved efficiency and market credibility. By incorporating panel data across multiple regions, econometric models allow researchers to control for confounding variables such as firm size, sectoral differences, and market openness. Furthermore, advanced econometric techniques, such as fixed-effects or instrumental variable regression, can disentangle causality, distinguishing whether standard adoption drives innovation or vice versa[50].
2. **Composite Indices:** Composite indices aggregate multiple KPIs into a single measure of integration and performance, facilitating cross-regional and international comparisons. Inspired by tools like the Global Innovation Index, such indices can capture dimensions of innovation capacity, sustainability, and inclusivity simultaneously[51]. This approach provides policymakers with a holistic snapshot of RIS integration into GSF. For instance, a regional composite index might combine metrics such as patent intensity, renewable energy adoption, and SME participation in international certification programs[52]. Weighting schemes can be applied to prioritize certain KPI,s such as sustainability or knowledge diffusion based on policy objectives. By standardizing diverse data sources, composite indices offer clarity for decision-making, while also highlighting regional strengths and weaknesses in relation to global benchmarks.
3. **Network Analysis:** Network analysis provides a powerful means to visualize and quantify RIS actor participation in global standardization processes. By mapping connections between universities, firms, and standardization bodies, network analysis can reveal structural properties such as centrality, density, and clustering[53]. For example, examining participation in ITU committees for 5G technologies may show whether RIS actors occupy peripheral or central roles in decision-making networks. Furthermore, social network analysis enables the study of knowledge diffusion, indicating how well information circulates between regional stakeholders and GS-setting institutions. This methodology also identifies structural gaps, such as the absence of SMEs or public research organizations in key forums, which may limit inclusivity and long-term competitiveness.

5.3.2. Qualitative Methodologies

1. **Case Studies:** Case studies provide contextual depth by examining how specific RIS engage with standardization processes. For instance, analyzing regional participation in renewable energy standards within the International Electrotechnical Commission (IEC) can reveal both institutional strengths and systemic barriers. Unlike purely statistical approaches, case studies capture informal dynamics, such as the role of trust, cultural norms, and stakeholder negotiation [54]. They allow researchers to compare successful integration experiences with less effective ones, offering valuable lessons for scaling good practices. Through longitudinal case designs, it becomes possible to trace how early-stage involvement in committees evolves into long-term benefits, such as improved export readiness or international recognition for regional technologies.
2. **Policy Analysis:** Policy analysis investigates the extent to which regional innovation policies align with international standardization priorities. By reviewing strategic documents, such as innovation roadmaps, industrial policies, and sustainability plans, researchers can assess coherence between regional goals and GS-setting agendas [55]. For example, an RIS promoting circular economy principles may achieve limited impact if its frameworks are not harmonized with ISO standards on environmental management. Policy analysis also highlights gaps, such as a lack of subsidies for SME certification or weak coordination between ministries and research institutions. Ultimately, this method reveals whether RIS governance structures are sufficiently adaptive to the evolving global landscape of standardization and innovation.
3. **Stakeholder Interviews:** Stakeholder interviews offer an avenue for capturing lived experiences, perceptions, and institutional dynamics that quantitative indicators often overlook. Interviews with SMEs, policymakers, researchers, and standardization representatives help identify both perceived opportunities and barriers to integration. For example, SMEs may highlight the prohibitive costs of compliance with GS, while policymakers may emphasize knowledge deficits and institutional asymmetries [45]. Semi-structured interview techniques ensure comparability across cases while allowing for the emergence of novel insights. Triangulated with quantitative findings, stakeholder perspectives enrich understanding by shedding light on the cultural and socio-political aspects of RIS participation in GSFs.
4. **Triangulation for Validity:** Importantly, triangulation strengthens the overall validity of research by combining quantitative rigor with qualitative depth [56]. For instance, econometric findings linking ISO certification with improved export performance gain credibility when paired with case studies documenting SME struggles with certification costs and bureaucracy. Similarly, network analysis showing marginal SME participation in global forums can be contextualized by interview data highlighting structural exclusion. This integrated approach ensures that results are not merely statistical abstractions but reflect the lived realities of RIS actors navigating complex global standardization ecosystems [57].

A further methodological challenge lies in data asymmetry. Advanced RIS often have comprehensive innovation data, while developing regions may lack reliable statistics. Addressing this requires capacity-building in measurement infrastructure and collaboration with global organizations such as OECD, World Intellectual Property Organization (WIPO), and WTO to harmonize indicators [58]. Ultimately, methodological approaches must be adaptive, capable of capturing both the diversity of regional contexts and the universality of GS. This methodological pluralism ensures that the comparative framework and KPIs do not merely describe performance but also guide policies toward more equitable and effective integration.

5.4. Applying the Framework: Applied Examples

To ensure the practical impact and relevance for policymakers, the Comparative Framework must move beyond theoretical mapping to offer applied, real-world examples. This framework is designed to be utilized through comparative case studies that demonstrate how different RIS approaches harmonize challenges. For instance, a comparison between Germany's Industry 4.0 Initiative (a highly codified, state-supported RIS focused on technical standards) and a Nordic Green Innovation Cluster (a decentralized, market-driven

RIS focused on environmental outcomes) would illustrate contrasting approaches to aligning local innovation with international ISO 9000 or ISO 14001 series[45]. The framework allows analysts to track the flow of tacit knowledge from the regional cluster into formal standardization bodies (an Upstream Harmonization KPI) and the rate at which global standards are adapted to local regulatory conditions (a Downstream Harmonization KPI). An applied example of this analysis is the case of smart grid standardization: A regional utility company in the European Union (EU) may pilot a smart metering technology. The framework would use the KPI of 'Standard Adoption Rate' to measure how quickly this regional innovation gains traction at the international level (e.g., in IEC standards) and the KPI of 'Inclusion Index' to assess whether non-dominant regional actors (e.g., SMEs from Southern Europe) were involved in the standard-setting process. By incorporating such applied examples, the framework demonstrates its value as a diagnostic tool for policy design, bridging the gap between localized experimentation and global coherence.

6. Implications and Future Directions

6.1. Synthesis of Findings and Theoretical Contributions

This paper contributes to the theoretical landscape by deepening the understanding of the dynamic interplay between RIS and GSF processes. Classical RIS literature has largely emphasized knowledge flows, institutional frameworks, and actor networks as central determinants of regional competitiveness[59]. However, the integration of GS introduces a novel dimension: how transnational regulatory architectures shape and constrain local innovation trajectories. By positioning standardization not merely as a technical benchmark but as a governance mechanism that structures access to global markets, this study reconceptualizes RIS as entities embedded within multi-scalar regimes of power and knowledge[55]. Consequently, the major theoretical advancement lies in linking RIS literature with global governance and standardization studies. Traditional innovation theories, such as evolutionary economics, often treat technological trajectories as path-dependent and shaped by endogenous capacities[60]. Yet, GS imposes exogenous pressures that may either reinforce or disrupt local trajectories. For instance, mandatory compliance with ISO 14001 environmental standards forces regions to align innovation pathways with sustainability imperatives, thereby embedding ecological considerations into theoretical models of RIS evolution. Furthermore, this study highlights the relational character of standards as boundary objects. Standards function as mediators across heterogeneous institutional logics, enabling inter-regional collaboration while also reinforcing hierarchies[61]. By examining RIS-standardization linkages, we refine theories of innovation ecosystems to account for asymmetries between developed and developing regions in their access to standardization forums. This contributes to a more critical understanding of how global institutions structure "innovation rents" and shape developmental pathways[40]. Finally, the paper challenges the implicit assumption of sovereignty in RIS scholarship. Instead, it theorizes RIS as nested systems where autonomy is constantly negotiated through compliance, adaptation, and contestation of standards. This reframing situates RIS within debates on digital sovereignty, sustainable transitions, and technological justice, thereby extending the theoretical scope of regional innovation studies into domains previously dominated by global political economy perspectives.

6.2. Policy Implications

From a policy standpoint, the findings underscore the urgent need for greater alignment between regional innovation strategies and global standardization regimes. Policymakers must recognize that the ability of RIS to compete globally depends not only on fostering endogenous capacities such as R&D investment but also on facilitating compliance with international norms. For emerging economies, the high cost of certification and limited access to standardization committees create structural disadvantages. Policy instruments such as targeted subsidies, technical assistance programs, and capacity-building initiatives are therefore critical for ensuring inclusive participation[45]. At the regional level, governments should institutionalize mechanisms for dialogue between firms, research institutions, and standardization bodies. For instance, innovation agencies could establish standardization observatories that track evolving international requirements and disseminate intelligence to SMEs. Such efforts would mitigate information asymmetries and enable firms to anticipate compliance costs. Moreover, em-

bedding standardization literacy into university curricula and vocational training would prepare future innovators to navigate complex regulatory environments [62].

International organizations, including the ISO and the WTO, also bear responsibility for reducing asymmetries in global governance. Policies promoting differential compliance pathways whereby developing regions adopt phased or context-specific versions of GS could reduce exclusionary effects. Furthermore, regional blocs such as the African Union (AU) or the EU can act as intermediaries, pooling resources to enhance bargaining power in standardization negotiations [63]. Critically, policymakers must balance global alignment with local priorities. Blind adoption of external standards risks reinforcing dependency and undermining regional innovation sovereignty. A good strategy should therefore blend compliance with selective contestation, ensuring that RIS retains agency in shaping standards. This dual approach would allow policymakers to safeguard local development trajectories while remaining integrated into the global economy.

6.3. Practical Implications

For firms, innovation clusters, and standard-setting bodies, the implications are both operational and strategic. SMEs, in particular, face significant challenges in meeting the financial and technical requirements of GS. Firms should view certification not merely as a compliance burden but as a strategic investment that enhances credibility in global markets. Empirical evidence suggests that ISO-certified firms enjoy superior export performance, innovation intensity, and reputational capital [64]. By adopting proactive approaches such as engaging in pre-standardization research consortia, firms can influence the standards themselves rather than merely responding to them. Innovation clusters also provide another important arena for practical action. Clusters can serve as collective platforms to share compliance costs, exchange technical expertise, and coordinate lobbying efforts in global standardization forums [65]. For example, renewable energy clusters in Scandinavia have effectively pooled resources to shape IEC standards, thereby securing market advantages for regional technologies. In contexts where individual SMEs lack capacity, clusters become vehicles for collective standardization strategies.

Standard-setting bodies, meanwhile, must reflect critically on their governance models. Current processes often favor large multinational corporations with resources to participate in multiple committees simultaneously. Greater inclusivity requires reforms such as tiered membership fees, translation services, and the inclusion of regional representatives in decision-making structures. Practical innovations like digital platforms for virtual participation could lower barriers for actors in resource-constrained RIS [66]. Furthermore, practical implications extend to knowledge management. Firms and clusters must cultivate absorptive capacity to internalize GS into their innovation practices [67]. This entails not only technical training but also cultural adaptation, as standardization often reflects the values and priorities of dominant economies. Thus, firms must navigate tensions between global compliance and local embeddedness, striking a balance that maximizes competitiveness while preserving regional identity.

6.4. Research Implications

The findings of this study open multiple avenues for future research on RIS-standardization linkages. One pressing area concerns digital sovereignty, the extent to which regions can control their digital infrastructures while complying with GS. Emerging debates on 5G, cloud computing, and cybersecurity standards reveal how technological sovereignty is becoming a geopolitical concern, demanding interdisciplinary research that spans innovation studies, international relations, and digital governance [68]. Another promising frontier lies in climate and sustainability standards. As global regulatory regimes increasingly emphasize carbon neutrality and circular economy practices, researchers must examine how RIS adapt to and influence these frameworks. Case studies of regions experimenting with ISO 14001 or the EU's Carbon Border Adjustment Mechanism could reveal both compliance strategies and opportunities for normative leadership [69]. Artificial intelligence ethics also presents fertile ground. Current efforts by the IEEE and ISO to codify AI ethics create new spaces where RIS actors must engage [70]. Research is needed on how regions, particularly in the Global South, can influence ethical frameworks that might otherwise be dominated by Silicon Valley or European perspectives. In addition, longitudinal research is needed to understand the evolutionary dynamics of RIS-standardization interactions. Questions such as: Do regions that initially comply with

external standards eventually acquire the capacity to shape them? Or do structural asymmetries persist, entrenching dependency? Mixed-methods studies combining econometric analysis, network mapping, and ethnographic approaches could provide deeper insights into these questions. Thus, by advancing research along these directions, researchers can contribute to a more balanced understanding of how GS both constrain and enable regional innovation, while identifying strategies for greater inclusivity and resilience in a rapidly changing technological landscape.

7. Conclusions

7.1. Key Conclusions and Theoretical Contribution

The core conclusion of this conceptual study is that achieving sustainable development critically depends on harmonizing the localized dynamics of Regional Innovation Systems (RIS) with the universal demands of Global Standardization Frameworks (GSF). The study's central finding is that polycentric governance is the necessary mechanism for mediating this tension, providing a political structure to manage inherent institutional asymmetries. Standards are reframed not merely as technical specifications but as boundary objects that both enable the global scaling of localized innovations and impose exogenous constraints on regional development. The Comparative Framework and Key Performance Indicators (KPIs) presented serve as the major prescriptive contribution, offering a systematic tool for policymakers and researchers to evaluate the actual performance and effectiveness of harmonization strategies in real-world contexts.

7.2. Limitations of the Study

The limitations of this work stem from its conceptual nature. First, as a conceptual and narrative review, the findings are based on a synthesis of existing literature, and the proposed Comparative Framework requires empirical validation. Second, the use of the RIS concept is limited by its often-criticized static, regionally-focused nature, presenting a theoretical challenge when applied to global governance. Third, while polycentric governance is proposed as the ideal solution, the study acknowledges its practical difficulty in overcoming the deeply entrenched power dynamics and dominance of developed countries in the standard-setting process.

7.3. Avenues for Future Research

Future research should focus on empirical validation and targeted governance challenges. Arising directly from the power asymmetry identified, the primary research agenda should be the longitudinal study of policy models designed to enhance the bargaining power and influence of developing regions within international standardization forums. Researchers must specifically investigate the efficacy of using the KPIs proposed in this paper to test the effectiveness of governance interventions and track performance outcomes. Further empirical work is needed to validate the Comparative Framework by applying its metrics across diverse RIS, specifically examining the impact of phased or differential compliance pathways on local innovation diffusion and global market access.

Author Contributions

Conceptualization, D.E.J.; writing—original draft preparation, D.E.J. and I.D.J.; writing—review and editing, D.E.J. and I.D.J.; visualization, D.E.J. All authors have read and agreed to the published version of the manuscript.

Funding

This work received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

All data and information supporting the paper available in all publicly domains.

Acknowledgments

The authors wish to acknowledge all the support received from reviewers and all colleagues who read through the work.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Cooke, P., 2001. Regional innovation systems, clusters, and the knowledge economy. Industrial and Corporate Change. 10(4), 945–974.

[2] Asheim, B.T., Grillitsch, M., Trippl, M., 2016. Regional innovation systems: Past–present–future. In Handbook on the Geographies of Innovation. Edward Elgar Publishing: Cheltenham, UK. pp. 45–62.

[3] Blind, K., 2016. The impact of standardisation and standards on innovation. In: Edler, J., Cunningham, P., Gök, A., et al. (Eds.). Handbook of Innovation Policy Impact. Edward Elgar Publishing: Cheltenham, UK. pp. 423–449.

[4] Bernini, G.N., 2023. Patent landscape on hydrogen technologies: Study of hydrogen technology specialisation across European regions.

[5] Blind, K., 2010. The Economics of Standardization: An Update. UK Department of Business, Innovation and Skills: London, UK. Available from: https://assets.publishing.service.gov.uk/media/5a790abd40f0b679c0a0812d/10-1135-economics-of-standardization-update.pdf

[6] Lee, B.X., Kjaerulf, F., Turner, S., et al., 2016. Transforming our world: Implementing the 2030 agenda through sustainable development goal indicators. Journal of Public Health Policy. 37(Suppl 1), 13–31.

[7] Blind, K., Mangelsdorf, A., 2016. Motives to standardize: Empirical evidence from Germany. Technovation. 48, 13–24.

[8] Schot, J., Steinmueller, W.E., 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. Research Policy. 47(9), 1554–1567.

[9] Lundvall, B.Å., 2010. Scope, style, and theme of research on knowledge and learning societies. Journal of Knowledge Economy. 1(1), 18–23.

[10] Edquist, C., 2019. Towards a holistic innovation policy: Can the Swedish National Innovation Council (NIC) be a role model? Research Policy. 48(4), 869–879.

[11] Tether, B.S., Metcalfe, J.S., 2004. Services and systems of innovation. In Sectoral Systems of Innovation. Cambridge University Press: Cambridge, UK. pp. 287–323.

[12] Theile, C.M., Beall, A.L., 2024. Narrative reviews of the literature: an overview. Journal of Dental Hygiene. 98(1), 78–82.

[13] Sukhera, J., 2022. Narrative reviews: flexible, rigorous, and practical. Journal of Graduate Medical Education. 14(4), 4.

[14] Su, Y., Yan, Y., 2023. The influence of the two-tier network of a regional innovation system on knowledge emergence. Journal of Knowledge Management. 27(9), 2526–2547.

[15] Piqué, J.M., Berbegal-Mirabent, J., Etzkowitz, H., 2020. The role of universities in shaping the evolution of Silicon Valley's ecosystem of innovation. Triple Helix. 7(2–3), 277–321.

[16] Binz, C., Truffer, B., 2017. Global innovation systems—a conceptual framework for innovation dynamics in transnational contexts. Research Policy. 46(7), 1284–1298.

[17] Viardot, E., McCarthy, I.P., Chen, J., 2021. Standardization in a digital and global world: state-of-the-art and future perspectives. IEEE Transactions on Engineering Management. 68(1), 11–17.

[18] Knorringa, P., Nadvi, K., 2016. Rising power clusters and the challenges of local and global standards. Journal of Business Ethics. 133(1), 55–72.

[19] Henson, S., Humphrey, J., 2010. Understanding the complexities of private standards in global agri-food chains as they impact developing countries. Journal of Development Studies. 46(9), 1628–1646.

[20] Obuseh, E., Eyenubo, J., Alele, J., et al., 2025. A systematic review of barriers to renewable energy integration and adoption. Journal of Asian Energy Studies. 9, 26–45.

[21] Wiener, A., Börzel,T.A., Risse, T., 2019. European Integration Theory. Oxford University Press: Oxford, UK.

[22] Jacob, D.E., Nelson, I.U., Izah, S.C., 2024. Indigenous water management strategies in the global south. In Water Crises and Sustainable Management in the Global South. Springer Nature: Singapore. pp. 487–525.

[23] Broome, A., Quirk, J., 2015. Governing the world at a distance: the practice of global benchmarking. Review of International Studies. 41(5), 819–841.

[24] Hojnik, J., Ruzzier, M., Ruzzier, M.K., et al., 2024. Review of EU projects with a focus on environmental quality: innovation, eco-innovation, and circular-economy elements. International Journal of Innovation Studies. 8(1), 1–12.

[25] Bernstein, S., van der Ven, H., 2017. Best practices in global governance. Review of International Studies. 43(3), 534–556.

[26] Ostrom, E., 2010. Beyond markets and states: polycentric governance of complex economic systems. American Economic Review. 100(3), 641–672.

[27] Pieraccini, M., 2019. Towards just resilience: representing and including new constituencies in adaptive

governance and law. Journal of Environmental Law. 31(2), 213–234.

[28] Lysenko, S., Liubchenko, A., Kozakov, V.D., et al., 2024. Global cybersecurity: harmonising international standards and cooperation. Multidisciplinary Reviews. 7, e2024spe021.

[29] Parrilli, M.D., Balavac, M., Radicic, D., 2020. Business innovation modes and their impact on innovation outputs: regional variations and the nature of innovation across EU regions. Research Policy. 49(8), 104047.

[30] Tassey, G., 2019. Regional technology-based economic development: policies and impacts in the US and other economies. Annals of Science and Technology Policy. 3(1), 1–141.

[31] Foray, D., 2014. Smart Specialisation: Opportunities and Challenges for Regional Innovation Policy. Routledge: London, UK.

[32] Gereffi, G., 2005. The global economy: organization, governance, and development. In The Handbook of Economic Sociology. Princeton University Press: Princeton, NJ, USA. pp. 160–182.

[33] Armeanu, S.D., Vintila, G., Gherghina, S.C., 2017. A cross-country empirical study towards the impact of following ISO management system standards on Euro-area economic confidence. Amfiteatru Economic. 19(44), 144–158.

[34] Akpobome, O., 2024. The impact of emerging technologies on legal frameworks: a model for adaptive regulation. International Journal of Research Publication Reviews. 5(10), 5046–5060.

[35] Freire, D.V.C., 2023. Mission-critical communications from LMR to 5G: a technology assessment approach for smart city scenarios [PhD Thesis]. Universidade NOVA de Lisboa: Lisbon, Portugal.

[36] Altenburg, T., Pegels, A., 2017. Sustainability-oriented innovation systems—managing the green transformation. In: Sustainability-Oriented Innovation Systems in China and India. Routledge: London, UK. pp. 17–34.

[37] Vang, J., Chaminade, C., 2006. Building RIS in Developing Countries: Policy Lessons from Bangalore, India. CIRCLE, Lund University: Lund, Sweden.

[38] Romanchyshyna, I., 2023. Technical Barriers to Trade in "New Generation" RTAs and in the WTO Agreements: Conflict or Complementarity? Springer Nature: Cham, Switzerland.

[39] Edler, J., Fagerberg, J., 2017. Innovation policy: what, why, and how. Oxford Review of Economic Policy. 33(1), 2–23.

[40] Ponte, S., 2019. Sustainability, global value chains and green capital accumulation. In Handbook on Global Value Chains. Edward Elgar Publishing: Cheltenham, UK. pp. 228–247.

[41] North, D.C., 1990. Institutions, Institutional Change and Economic Performance. Cambridge University Press: Cambridge, UK.

[42] Archibugi, D., Filippetti, A. (Eds.), 2015. The Handbook of Global Science, Technology, and Innovation. Wiley: Hoboken, NJ, USA.

[43] Malecki, E.J., 2011. Connecting local entrepreneurial ecosystems to global innovation networks: open innovation, double networks and knowledge integration. International Journal of Entrepreneurship and Innovation Management. 14(1), 36–59.

[44] O'Connell, D., Walker, B., Abel, N., et al., 2015. The Resilience, Adaptation and Transformation Assessment Framework: From Theory to Application. Commonwealth Scientific and Industrial Research Organisation: Canberra, Australia.

[45] Yaghmaei, E., 2018. Responsible research and innovation key performance indicators in industry: a case study in the ICT domain. Journal of Information, Communication and Ethics in Society. 16(2), 214–234.

[46] Le, D.N., Nguyen, V.H., 2024. Does quality certification or product diversification improve the performance of small and medium enterprises? Sustainability. 16(5), 2023.

[47] Del Río, P., Romero-Jordán, D., Peñasco, C., 2017. Analysing firm-specific and type-specific determinants of eco-innovation. Technological and Economic Development of Economy. 23(2), 270–295.

[48] Creswell, J.W., Clark, V.L.P., 2017. Designing and Conducting Mixed Methods Research. Sage Publications: Thousand Oaks, CA, USA.

[49] Wilcock, A.E., Boys, K.A., 2017. Improving quality management: ISO 9001 benefits for agrifood firms. Journal of Agribusiness in Developing and Emerging Economies. 7(1), 2–20.

[50] Kubitza, C., Krishna, V.V., 2020. Instrumental variables and the claim of causality: evidence from impact studies in maize systems. Global Food Security. 26, 100383.

[51] Ujwary-Gil, A., Florek-Paszkowska, A., 2025. Introduction to the Innovability Index: more than the fusion of innovation and sustainability. Journal of Entrepreneurship, Management and Innovation. 21(2), 5–14.

[52] Dutta, G., Kumar, R., Sindhwani, R., et al., 2021. Digitalization priorities of quality control processes for SMEs: a conceptual study in perspective of Industry 4.0 adoption. Journal of Intelligent Manufacturing. 32(6), 1679–1698.

[53] Lagoke, O., Adesola, S., Soname, S., 2021. Social network analysis as a methodological tool to understand university–industry dynamism in enhancing the HEI curriculum: a case of the Nigerian oil industry. Studies in Higher Education. 46(11), 2417–2430.

[54] Yin, R.K., 2018. Case Study Research and Applications. 6th ed. Sage Publications: Thousand Oaks, CA, USA.

[55] Kuhlmann, S., Rip, A., 2018. Next-generation innova-

tion policy and grand challenges. Science and Public Policy. 45(4), 448–454.

[56] Meydan, C.H., Akkaş, H., 2024. The role of triangulation in qualitative research: converging perspectives. In Principles of Conducting Qualitative Research in Multicultural Settings. IGI Global: Hershey, PA, USA. pp. 98–129.

[57] Tödtling, F., Trippl, M., Desch, V., 2022. New directions for RIS studies and policies in the face of grand societal challenges. European Planning Studies. 30(11), 2139–2156.

[58] Bandola-Gill, J., Grek, S., Tichenor, M., 2022. Harmonising global public policy: producing global standards, local data and statistical capacity development. In Governing the Sustainable Development Goals: Quantification in Global Public Policy. Palgrave Macmillan: Cham, Switzerland. pp. 41–67.

[59] Brekke, T., 2021. What do we know about the university contribution to regional economic development? A conceptual framework. International Regional Science Review. 44(2), 229–261.

[60] Ruttan, V.W., 2010. Sources of technical change: induced innovation, evolutionary theory, and path dependence. In Technological Change and the Environment. Routledge: London, UK. pp. 9–39.

[61] Wijen, F., 2014. Means versus ends in opaque institutional fields: trading off compliance and achievement in sustainability standard adoption. Academy of Management Review. 39(3), 302–323.

[62] Xinming, Z., 2023. Research on cultivating innovation and practical skills in higher vocational education. Frontiers in Education Research. 6(26), 29–36.

[63] Bach, D.C., 2016. Cross-border interactions and regionalism. In Region-Building in Africa: Political and Economic Challenges. Palgrave Macmillan: New York, NY, USA. pp. 71–88.

[64] Pacheco, L., Lobo, C., Maldonado, I., 2022. Do ISO certifications enhance internationalization? The case of Portuguese industrial SMEs. Sustainability. 14(3), 1335.

[65] Babin, A., Ciloci, R., Davydenko, N., 2025. Perspectives of sustainable development of cluster organizations through internationalization and dual use. Smart Cities and Regional Development Journal. 9(3), 99–120.

[66] Wu, M., Gao, Y., Song, Q., et al., 2025. Integrated resource collaboration for RIS-assisted digital-twin-empowered Internet of Everything. IEEE Internet of Things Journal. 12, 23275–23287.

[67] Claver-Cortés, E., Molina-Castillo, F.J., López-Sánchez-García, E., et al., 2020. A literature review on the effect of industrial clusters and the absorptive capacity on innovation. International Journal of Industrial and Manufacturing Engineering. 14(7), 494–503.

[68] Chari, S.G., 2025. Power, pixels, and politics: the geopolitics of emerging technologies in the digital age. London Journal of Research in Humanities and Social Sciences. 25(2), 1–99.

[69] Erdogdu, E., 2025. The carbon border adjustment mechanism: opportunities and challenges for non-EU countries. Wiley Interdisciplinary Reviews: Energy and Environment. 14(1), e70000.

[70] Jedlickova, A., 2024. Ensuring ethical standards in the development of autonomous and intelligent systems. IEEE Transactions on Artificial Intelligence. 5(12), 5863–5870.