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Modeling Tomorrow: Innovation for Sustainable Development Innovation Systems, Technological Capabilities, and Sustainability Transitions in Latin America and the Caribbean



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Modeling Tomorrow: Innovation for Sustainable Development

Innovation Systems, Technological Capabilities, and Sustainability Transitions in Latin America and the Caribbean

CHAPTER II.

II. Building Innovation Capabilities in Small and Open Economies

Caribbean Innovation Hubs as Catalysts for Emerging National Innovation Systems in Small Economies

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1. Introduction

Innovation capacity is widely recognised as a key driver of economic transformation, productivity growth, and long-term competitiveness. The concept of National Innovation Systems (NIS) explains how interactions among firms, universities, research institutions, and governments shape the creation, diffusion, and commercialisation of knowledge (Freeman, 1987; Lundvall, 2007; Nelson & Winter, 1982. Within this framework, innovation outcomes depend not only on the strength of individual institutions but also on the quality and effectiveness of relationships among them (Morrar & Arman, 2024).

While the NIS framework has been widely applied in advanced economies, its implementation in Small Island Developing States (SIDS) has been uneven (Soete, Verspagen, & Ter Weel, 2010; Weerasinghe, Jayawardane, & Huang, 2024). Structural constraints, including limited research capacity, narrow domestic markets, fragmented institutional coordination, and restricted access to finance, often inhibit the emergence of robust innovation systems (Edquist & Hommen, 2008; Wilson, Maharaj, & Maharaj, 2020). These constraints are particularly evident in the Caribbean region, where governments increasingly emphasise innovation-led development but continue to face ecosystem gaps that constrain research commercialisation and technology-based entrepreneurship (Allahar & Sookram, 2019; King et al., 2012).

Despite the presence of universities and research institutions across the region, innovation activity frequently occurs in isolated pockets rather than within coordinated national systems (Allahar & Sookram, 2019; King et al., 2012; Wilson, Maharaj, & Maharaj, 2020). This paper therefore examines how innovation hubs can function as transitional institutional mechanisms that strengthen ecosystem linkages and support the gradual emergence of National Innovation Systems in small economies, drawing on the wider literature on innovation intermediaries as brokers that perform functions individual firms and universities cannot perform alone (Howells, 2006; Klerkx & Leeuwis, 2009). To organise this argument, the paper develops the Caribbean Innovation Hub Ecosystem Catalyst Framework, a conceptual model built around four interconnected pillars linked in a networked, multidirectional structure. The paper is structured as follows: Section 2 reviews the literature on National Innovation Systems, the university third mission, innovation intermediaries, and non-linear models of innovation; Section 3 outlines the methodological approach used to develop the framework; Section 4 presents the Caribbean Innovation Hub model and the four-pillar networked framework; and Section 5 discusses policy implications.

2. Literature Review

The literature on National Innovation Systems highlights the systemic nature of innovation. Freeman (1987) and Lundvall (2007) argue that innovation arises from interactions among firms, research institutions, government agencies, and financial actors that collectively shape technological change and economic development. Nelson and Winter (1982) similarly frame innovation as an evolutionary process embedded in institutional routines rather than a discrete, linear event, reinforcing the view that innovation capacity is a property of systems rather than of individual actors.

Universities increasingly play a central role in this process. Beyond teaching and research, many institutions now pursue a "third mission" involving technology transfer, entrepreneurship, and collaboration with industry (Gibb & Hannon, 2006; Vefago, Trierweiller, & Barcellos de Paula, 2020). Mechanisms such as Technology Transfer Offices (TTOs), incubators, and collaborative research programmes facilitate the commercialisation of knowledge generated within universities (Siegel, Veugelers, & Wright, 2007; Beltrán-Morales et al., 2020).

A related strand of literature examines the role of intermediary institutions in innovation systems more broadly. Howells (2006) argues that innovation intermediaries perform essential brokering functions, scanning for information, matching partners, and building trust, that individual firms and universities cannot perform for themselves. Klerkx and Leeuwis (2009) extend this argument by showing how innovation brokers become embedded at different levels of a system, from single transactions to system-wide coordination, and that their effectiveness depends on legitimacy with the actors they connect. This intermediary function is central to how Caribbean Innovation Hubs are conceptualised in this paper: as institutions that perform brokering work the market does not otherwise supply.

However, innovation systems in developing economies often face structural constraints. These include low levels of research and development investment, weak university-industry collaboration, fragmented policy coordination, and limited venture capital (Soete, Verspagen, & Ter Weel, 2010). In the Caribbean context specifically, research highlights persistent challenges such as limited research commercialisation, weak entrepreneurial culture, and low levels of private investment in innovation (Allahar & Sookram, 2019; King et al., 2012). These constraints suggest that innovation ecosystems in small economies may require institutional arrangements that are more networked and adaptive than those found in larger economies.

2.1 Non-Linear and Networked Models of Innovation

The National Innovation Systems literature reviewed above and the Triple Helix tradition introduced below are complementary rather than competing frameworks. Etzkowitz and Leydesdorff (2000) explicitly positioned the Triple Helix as a refinement of national-systems thinking rather than an alternative to it: where NIS scholarship maps which institutional actors, universities, firms, financial actors, and government, a functioning innovation system requires, it says comparatively little about how those actors must relate to one another for the system to behave as a system. The Triple Helix and its extensions supply that missing mechanism, treating university-industry-government relations as reciprocal and overlapping rather than fixed, and Leydesdorff (2012) extends this into an N-tuple of helices whose synergy can be measured statistically rather than merely assumed. In this paper, National Innovation Systems describe the outcome Caribbean Innovation Hubs are intended to help produce, while Triple and Quadruple

Helix theory supplies the structural justification for modelling the CIH framework itself as fully networked rather than linear.

A parallel strand of literature has moved away from linear, sequential accounts of innovation altogether. The Triple Helix model reconceived university-industry-government relations as non-linear and reciprocal, with each sphere able to take on functions traditionally associated with another, rather than passing knowledge along a fixed chain (Etzkowitz & Leydesdorff, 2000). Carayannis and Campbell (2009) extended this into a Quadruple Helix framed explicitly as a fractal innovation ecosystem, and Leydesdorff (2012) demonstrates that synergy within such systems can be measured precisely because information circulates among actors in multiple directions rather than along a single path. The entrepreneurial ecosystems literature reaches a similar conclusion from a different starting point: Spigel (2017) argues that ecosystem attributes are relationally organised rather than sequentially produced, Stam (2015) warns against policy models that treat ecosystem elements as inputs to a linear production function, and Adner (2017) proposes modelling ecosystem actors as a multilateral network of interdependent activities rather than a chain of bilateral exchanges. This literature informs the networked structure of the conceptual model developed in Section 4.

2.2 National Innovation Systems in Small Economies

Small economies face structural limitations that complicate the development of coherent National Innovation Systems. These limitations include small research communities, constrained fiscal resources, and limited access to venture capital or angel investment. As a result, innovation activities frequently occur through isolated initiatives rather than coordinated systems of institutions (Wilson, Maharaj, & Maharaj, 2020).

These challenges are particularly relevant for SIDS, where economic vulnerability, geographic fragmentation, and limited economies of scale constrain the development of extensive innovation infrastructures. Universities may possess research capabilities but lack mechanisms to connect effectively with industry and investors, while firms may perceive academic research as disconnected from commercial needs

In the Caribbean, this disconnect between knowledge production and market application has contributed to relatively low levels of patenting, technology licensing, and university spin-offs. At the same time, expenditure on research and development remains modest across many Caribbean economies, limiting the development of innovation-driven industries. These ecosystem gaps highlight the need for intermediary institutional structures capable of strengthening linkages between knowledge producers, entrepreneurs, investors, and policymakers.

3. Methodology

This paper adopts a qualitative, desk-based conceptual research approach. It draws on a structured review of the academic literature on National Innovation Systems, the entrepreneurial university, technology transfer, and innovation intermediaries, read alongside Caribbean-specific research on university-industry collaboration and entrepreneurial ecosystems (Allahar & Sookram, 2019; King et al., 2012). No primary data collection or statistical analysis was undertaken; the paper's contribution is conceptual rather than empirical.

The Caribbean Innovation Hub Ecosystem Catalyst Framework presented in Section 4 was developed inductively. The authors identified the institutional functions most consistently associated with successful innovation intermediaries in the literature, namely knowledge generation, network formation, market-facing commercialisation, and policy support, and mapped these functions onto four pillars: knowledge anchoring, ecosystem connectivity, market integration, and institutional coordination. The pillars were then juxtaposed against the specific structural constraints documented for Caribbean and other SIDS economies (limited research capacity, narrow domestic markets, fragmented coordination, and restricted access to finance), to ensure the framework speaks to conditions in small economies rather than simply importing a model developed for larger systems. The relationships among the four pillars were subsequently revised from a single sequential cycle into a fully networked structure, in which every pillar connects bidirectionally to every other pillar, in order to align the framework with the non-linear, multidirectional relationships documented in the Triple Helix, Quadruple Helix, and entrepreneurial ecosystems literatures (Etzkowitz & Leydesdorff, 2000; Carayannis & Campbell, 2009; Leydesdorff, 2012; Spigel, 2017; Stam, 2015; Adner, 2017). The resulting framework is intended as a conceptual and policy tool: a basis for future empirical testing through pilot implementation, rather than a finding derived from data on existing Caribbean hubs.

4. Analysis of Results

4.1 Caribbean Innovation Hubs as Intermediary Institutions

This paper advances the concept of Caribbean Innovation Hubs (CIH) as intermediary institutional platforms designed to address the coordination gaps that characterise innovation ecosystems in contexts where formal National Innovation Systems remain underdeveloped. In fragmented and institutionally thin environments, CIHs can be understood as mechanisms that build linkages, support knowledge diffusion, and strengthen institutional capacity, particularly in developing-country settings (Watkins, Papaioannou, Mugwagwa, & Kale, 2015). The model envisions a distributed innovation architecture anchored in universities but extending across firms, government agencies, investors, and research institutions. Within this architecture, CIHs may serve as evolving university-industry coordination mechanisms that facilitate knowledge transfer and collaboration across multiple actors in the innovation ecosystem (Albats, Alexander, & Cunningham, 2022). By connecting these actors within a more coherent collaborative framework, CIHs are intended to improve the conditions for innovation to move beyond research settings into productive and market-oriented applications.

The model operates through three interconnected mechanisms. First, network formation: innovation hubs create collaborative environments where entrepreneurs, firms, researchers, policymakers, and investors interact regularly, facilitating knowledge exchange, trust building, and the development of innovation networks. Second, institutional bridging: in fragmented innovation environments, hubs function as connectors linking universities, start-ups, government agencies, and private sector actors that might otherwise operate in relative isolation, reducing coordination failures and improving knowledge diffusion across the ecosystem. Third, capability development: innovation hubs support entrepreneurial capabilities by encouraging venture creation, mentoring innovators, and facilitating the commercialisation of research through partnerships with firms and investors.

4.2 Market Integration as a Critical Success Factor

A central proposition of this model is that private sector engagement represents a critical success factor. Firms and investors provide not only financial capital but also market knowledge, commercialisation pathways, and demand signals that allow innovation to move beyond research environments into productive economic activity. In this sense, Caribbean Innovation Hubs function as ecosystem-building platforms that integrate universities, industry, and investors within a collaborative regional innovation network.

4.3 The Caribbean Innovation Hub Ecosystem Catalyst Framework

This paper proposes the Caribbean Innovation Hub Ecosystem Catalyst Framework, which identifies four interconnected pillars, knowledge anchoring, ecosystem connectivity, market integration, and institutional coordination, that enable innovation hubs to function as catalysts for emerging innovation systems in small economies. The framework is presented in Figure 1.

Pillar one, knowledge anchoring, positions universities as the foundational institutions within emerging innovation ecosystems. Through research activity, talent development, and interdisciplinary collaboration, they generate the knowledge base necessary for technological advancement and entrepreneurial activity (Gibb & Hannon, 2006; Vefago, Trierweiller, & Barcellos de Paula, 2020). Within the CIH model, universities anchor the ecosystem by supporting technology transfer, fostering university-industry collaboration, and developing human capital capable of participating in innovation-driven economic activity; mechanisms such as Technology Transfer Offices, incubators, and entrepreneurship programmes help translate research outputs into commercially viable innovations (Siegel, Veugelers, & Wright, 2007; Beltrán-Morales et al., 2020). This pillar is not self-contained: the Triple Helix literature shows that university knowledge only translates into innovation once it is linked to industry and government (Etzkowitz & Leydesdorff, 2000), which is precisely the bridging function performed by the ecosystem connectivity pillar below.

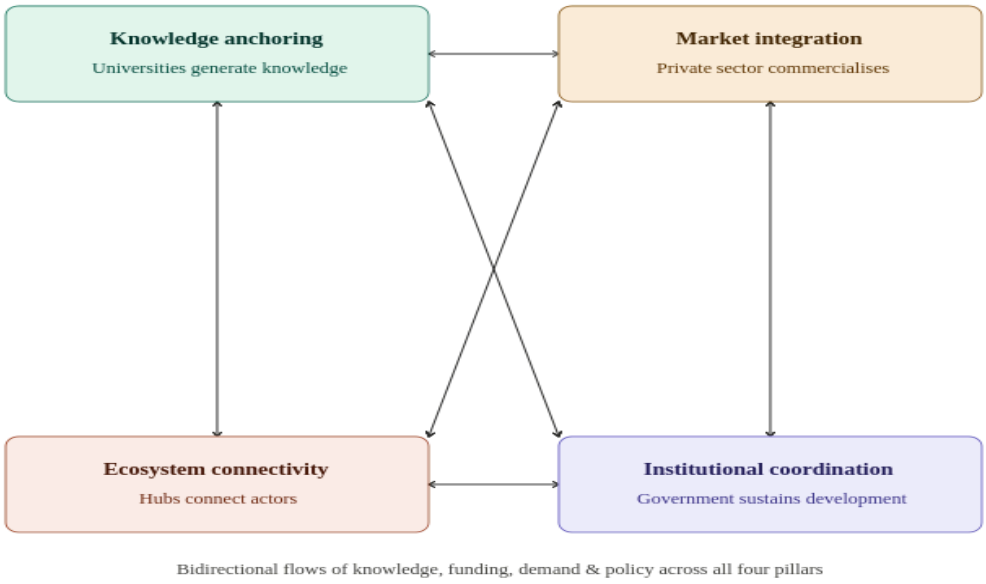
Pillar two, ecosystem connectivity, reflects the dependence of innovation ecosystems on sustained interaction among diverse actors. Innovation hubs facilitate network formation by creating structured environments where entrepreneurs, researchers, firms, policymakers, and investors interact regularly, performing the brokering functions that individual firms and universities cannot perform for themselves (Howells, 2006; Klerkx & Leeuwis, 2009). Activities such as innovation forums, mentorship programmes, accelerator initiatives, and industry-academic partnerships help strengthen these relationships and reduce the fragmentation that often characterises innovation activity in small economies. This connectivity function is what distinguishes the CIH model from earlier, linear accounts of innovation: rather than knowledge moving in one direction from universities to firms, connectivity allows knowledge anchoring, market integration, and institutional coordination to inform one another continuously, consistent with Quadruple Helix accounts of innovation as a fractal ecosystem of overlapping actors (Carayannis & Campbell, 2009).

Pillar three, market integration, reflects the role of firms and investors in contributing market intelligence, technological demand, and commercialisation pathways alongside financial resources (Spigel, 2017; Stam, 2015). Within the CIH framework, private sector participation helps ensure that innovation efforts remain aligned with market needs; partnerships between firms, start-ups, and universities can accelerate the commercialisation of research while

attracting venture capital and other forms of investment necessary to scale innovation-driven enterprises (Allahar & Sookram, 2019). Market integration therefore depends on, and reinforces, both knowledge anchoring and ecosystem connectivity: firms cannot commercialise research they cannot access, and hubs cannot sustain networks without firms willing to invest in what those networks produce (Adner, 2017).

Pillar four, institutional coordination, reflects the enabling role of government institutions in establishing regulatory frameworks, policy incentives, and infrastructure that support innovation activity (Watkins, Papaioannou, Mugwagwa, & Kale, 2015). Within the CIH framework, governments support ecosystem growth through intellectual property frameworks, innovation policy strategies, research funding, and coordination among public institutions, creating an enabling environment that encourages collaboration between universities, firms, and investors (OECD, 2024). As the Triple Helix and its extensions make clear, institutional coordination is not a downstream outcome of the other three pillars but an active participant in shaping them: government policy can accelerate or constrain knowledge anchoring, connectivity, and market integration alike (Etzkowitz & Leydesdorff, 2000).

Figure 1. The Caribbean Innovation Hub Ecosystem Catalyst Framework as a networked, multidirectional model



Source: Authors' own construction.

Figure 1 deliberately departs from a single sequential pipeline. Rather than depicting knowledge flowing in one direction from universities through hubs and firms to government, the framework connects every pillar to every other pillar: four side connections plus two crossing diagonal connections, each bidirectional. This reflects the reality that knowledge, funding, demand signals, and policy incentives move in multiple directions simultaneously, universities respond to market signals from firms just as firms draw on university research; government funding

For Caribbean economies and other SIDS seeking to deepen innovation capacity, the CIH model offers a pragmatic pathway toward ecosystem development and the gradual consolidation of stronger National Innovation Systems. Looking ahead, the authors intend to pilot the Ecosystem Catalyst Framework at one or two Caribbean campuses, tracking indicators aligned with each pillar, university technology-transfer activity, hub-facilitated partnerships, private sector co-investment, and policy or regulatory change, to test empirically whether the networked, multidirectional dynamic proposed in Figure 1 holds in practice.

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