REVISTA ELECTRÓNICA TRIMESTRAL
VOL. 10. NÚM. 3 (2026)
ISSN: 2594-0937

DEBATES SOBRE INNOVACIÓN

NACLICS SPECIAL ISSUE

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



Casa abierta al tiempo
UNIVERSIDAD AUTÓNOMA METROPOLITANA
Unidad Xochimilco
DMEGI

DEBATES SOBRE INNOVACIÓN. Volumen 10, Número 3, Julio-septiembre de 2026, es una publicación trimestral de la Universidad Autónoma Metropolitana a través de la Unidad Xochimilco, División de Ciencias Sociales y Humanidades, Departamento de Producción Económica. Prolongación Canal de Miramontes 3855, Col. Ex-Hacienda San Juan de Dios, Alcaldía Tlalpan, C.P.14387, Ciudad de México y Calzada del Hueso 1100, Col.Villa Quietud, Alcaldía Coyoacán, C.P.04960, Ciudad de México. Teléfono 55 54837200, ext.7279. Página electrónica de la revista https://revistadebates.xoc.uam.mx/index.php/debinnovacion/issue/view/17 y dirección electrónica: noticiaslalics@gmail.com Editor responsable: Dra. Gabriela Dutrénit Bielous. Certificado de Reserva de Derechos al Uso Exclusivo de Título **No. 04-2022-101113015800-102. ISSN 2594-0937**, ambos otorgados por el Instituto Nacional del Derecho de Autor. Responsable de la última actualización de este número: Dra. Maribel García Barrientos y Dr. Guillermo Andrés Alpízar, Departamento de Producción Económica, División de Ciencias Sociales y Humanidades, Unidad Xochimilco. Calzada del Hueso 1100, Col.Villa Quietud, Alcaldía Coyoacán, C.P. 04960, Ciudad de México. Fecha de última modificación: 13 de noviembre de 2026. Tamaño del archivo: 3.5 MB Las opiniones expresadas por los autores no necesariamente reflejan la postura del editor de la publicación. Queda estrictamente prohibida la reproducción total o parcial de los contenidos e imágenes de la publicación sin previa autorización de la Universidad Autónoma Metropolitana.

Modeling Tomorrow: Innovation for Sustainable Development

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

Introduction: Innovation Systems in a Changing Development Landscape

Alejandra Rosales Soto
CETYS Universidad, Tijuana, Mexico, alejandra.rosales@cetys.mx

Innovation has long been recognized as a central driver of economic development, technological learning, and structural transformation. However, contemporary development challenges require a broader understanding of the processes through which knowledge, institutions, technologies, and productive capabilities interact to address societal needs. Climate change, economic vulnerability, digital transformation, institutional fragmentation, and persistent social inequalities have renewed interest in the role of innovation systems in shaping sustainable and inclusive development.

For Latin America and the Caribbean, these challenges are particularly significant. The region encompasses economies with distinct productive structures, institutional capabilities, and levels of technological development, while sharing important structural constraints related to external dependence, uneven access to knowledge, and limited coordination among innovation actors. Small island developing states face additional vulnerabilities associated with geographical scale, climate exposure, narrow markets, and dependence on international technological and financial networks. Against this background, the innovation systems perspective provides a valuable framework for examining how countries, regions, organizations, and communities develop the capabilities necessary to respond to economic, environmental, and social challenges. Rather than treating innovation solely as the commercialization of new technologies, this perspective emphasizes interactive learning, institutional relationships, knowledge circulation, and the conditions under which technological change contributes to development.

This special issue of ***Debates sobre Innovación*** brings together nine contributions associated with the **NACLICS 2026 PhD Academy and Research Conference**, held at The University of the West Indies, Cave Hill Campus, Barbados, in June 2026, under the theme *Modeling Tomorrow: Innovation for Sustainable Development.* The academy provided a platform for academic exchange among researchers, doctoral scholars, and practitioners interested in the relationships between innovation, technological capabilities, public policy, and sustainable development. Building upon these discussions, the present collection offers

conceptual, empirical, and policy-oriented perspectives on the opportunities and limitations of innovation-led development in small, emerging, and structurally diverse economies.

2. Reconsidering Innovation Systems and Ecosystems

The opening contributions revisit the conceptual foundations of innovation systems and examine their relevance to contemporary development challenges. Revisiting National Systems of Innovation in the UN SDGs Era (2016–2026) reassesses the National Systems of Innovation framework in relation to the United Nations Sustainable Development Goals. Through conceptual synthesis and an examination of contemporary policy developments, the article highlights the continuing relevance of national coordination, institutional relationships, and mission-oriented innovation policies. Its discussion of Canada provides an additional perspective on the tensions between technological capabilities, economic sovereignty, and sustainable development.

Complementing this contribution, Innovation Ecosystems and the Cluster as a Unit of Analysis: A Systematic Review with Perspectives for Latin American Industrial Clusters Examines the innovation ecosystem concept through a systematic literature review. By considering industrial clusters as potential units of analysis, the study contributes to the discussion of how interdependent actors, institutional arrangements, and productive relationships can be examined within territorial innovation processes. Taken together, these contributions encourage a reconsideration of the analytical boundaries of innovation systems. They also emphasize the importance of selecting appropriate units of analysis and recognizing the interactions among national, regional, and organizational processes.

3. Technological Capabilities and Structural Transformation in Small and Open Economies

A second group of contributions explores how innovation capabilities emerge and evolve under conditions of economic openness, institutional limitations, and external dependence.

Caribbean Innovation Hubs as Catalysts for Emerging National Innovation Systems in Small Economies develops a conceptual framework in which innovation hubs operate as

intermediary institutions connecting universities, firms, governments, and other ecosystem actors. The proposed framework emphasizes knowledge anchoring, ecosystem connectivity, market integration, and institutional coordination as mutually reinforcing dimensions of innovation system development.

Internationally Embedded Innovation Systems in Caribbean SIDS: Converting External Knowledge into Local Technological Capability extends this discussion by examining the relationship between international knowledge flows and domestic technological learning. Rather than viewing external dependence exclusively as a weakness, the contribution highlights the institutional arrangements through which external knowledge may be absorbed, adapted, and retained as local problem-solving capability.

The relationship between economic transformation and productive capabilities is further examined in *Economic Diversification and Employment Patterns in Emerging Oil Economies: Insights from Guyana.* Focusing on the challenges associated with rapid petroleum-led growth, the article considers the implications of resource dependence, labor-market adjustments, and economic diversification for long-term development.

At the organizational level, *Compliance as Catalyst: Digital-Sustainable Capability Building in a Border-Region Economy* examines the relationship between export participation, formal certification, and digital and sustainable transformation maturity among firms in Tijuana, Mexico. The study identifies associations between external compliance exposure and higher levels of transformation maturity, while recognizing the limitations of causal interpretation.

Collectively, these contributions suggest that technological capability building should be examined as a relational and context-dependent process. Access to international markets, technologies, or knowledge does not automatically produce productive transformation. The development of domestic capabilities depends on institutional coordination, organizational learning, and mechanisms that connect external opportunities with local economic and technological structures.

4. Institutional Coordination and Sustainability Transitions

The third group of articles addresses the institutional, financial, and technological dimensions of environmental sustainability, with particular attention to Jamaica.

Climate Investment Sequencing in Small Island Developing States: Jamaica's Climate Investment Strategy (2026–2040) examines how the sequencing of public investments can influence the feasibility and institutional sustainability of climate strategies. By considering investment dependencies, financing conditions, and adaptive decision rules, the article advances a policy-oriented approach to coordinating climate investment under uncertainty and limited implementation capacity.

Modelling an Integrated Waste-to-Energy PPP for Jamaica investigates an integrated waste-management and energy-recovery option through a public-private partnership framework. The proposed model considers technical design, financial feasibility, institutional coordination, environmental safeguards, and the development of local operational capabilities. Its contribution is particularly relevant to understanding the conditions under which infrastructure projects may support circular-economy objectives.

These studies illustrate the importance of moving beyond technological solutions in isolation. Sustainability transitions require institutional arrangements capable of coordinating investments, allocating risks, strengthening implementation capabilities, and ensuring accountability. They also demonstrate the value of examining the feasibility and developmental implications of proposed interventions before assuming their effectiveness.

5. Knowledge Mobilization and Social Sustainability

The final contribution extends the discussion of innovation systems to the social dimensions of sustainable development.

Knowledge Mobilization and Social Sustainability in Health Based on the Case of Diabetes in Mexico examines the relationships among knowledge production, dissemination, demand, and application within health innovation systems. Using diabetes in Mexico as a reference case, the paper discusses the institutional and relational barriers that may prevent scientific knowledge from being translated into effective responses to complex social problems. The article broadens the perspective of this special issue by emphasizing that innovation outcomes should not be assessed exclusively through productivity, technological adoption, or economic growth. The ability of innovation systems to address social needs also depends on

knowledge mobilization, institutional articulation, and the inclusion of diverse actors in processes of problem identification and solution development.

6. Contributions of the Special Issue and Future Research Directions

Despite their differences in geographical scope, analytical approach, and sectoral focus, the nine contributions share a concern with the conditions under which innovation can support sustainable development.

Three cross-cutting themes emerge from the collection.

I) First, institutional coordination remains fundamental to innovation system development. Whether examining national policy frameworks, Caribbean innovation hubs, industrial clusters, climate investment portfolios, or health systems, the contributions draw attention to the relationships among actors and the institutional arrangements necessary to sustain collective action.

II) Second, technological capability requires more than access to resources and knowledge. The relationship between international embeddedness, regulatory pressures, technological learning, and productive transformation highlights the need to understand how capabilities are acquired, adapted, and retained within economic and organizational contexts.

III) Third, sustainable development depends on the direction and social purpose of innovation. Climate resilience, resource diversification, circular-economy infrastructure, organizational sustainability, and public health demonstrate that innovation must be considered in relation to the broader outcomes it is expected to support.

These themes point toward a research agenda concerned with the governance, measurement, and development of innovation capabilities in structurally diverse economies. Future research could explore the mechanisms through which innovation intermediaries strengthen local capabilities, the conditions under which international technological relationships

support domestic learning, and the institutional requirements for effective sustainability transitions. Additional attention should be given to evaluating implementation outcomes, identifying distributional effects, and examining how knowledge can be mobilized across institutional and disciplinary boundaries.

The NACLICS 2026 PhD Academy and Research Conference provided an important setting for these discussions, connecting innovation scholarship with practical development challenges across Latin America and the Caribbean. The contributions assembled in this special issue reflect the value of continued regional and international dialogue on innovation, sustainability, and structural transformation. Ultimately, Modeling Tomorrow requires more than anticipating technological change. It calls for a deeper understanding of how innovation systems can be organized, strengthened, and directed toward development outcomes that are economically viable, environmentally responsible, and socially inclusive.

*** We would like to thank Alexandre González Seijo for his help with the cover design, as well as Alejandra Rosales Soto for her contribution to the editing of this issue.

Contents

1. ***Revisiting National Systems of Innovation in the UN SDGs Era (2016–2026)*** *10*
2. ***Innovation Ecosystems and the Cluster as a Unit of Analysis: A Systematic Review with Perspectives for Latin American Industrial Clusters*** *22*
3. ***Caribbean Innovation Hubs as Catalysts for Emerging National Innovation Systems in Small Economies*** *31*
4. ***Internationally Embedded Innovation Systems in Caribbean SIDS: Converting External Knowledge into Local Technological Capability*** *40*
5. ***Economic Diversification and Employment Patterns in Emerging Oil Economies: Insights from Guyana*** *48*
6. ***Compliance as Catalyst: Digital-Sustainable Capability Building in a Border-Region Economy*** *58*
7. ***Climate Investment Sequencing in Small Island Developing States: Jamaica's Climate Investment Strategy (2026–2040)*** *68*
8. ***Modelling an Integrated Waste-to-Energy PPP for Jamaica*** *77*
9. ***Knowledge Mobilization and Social Sustainability in Health Based on the Case of Diabetes in Mexico*** *87*

CHAPTER 1

I. Rethinking Innovation Systems and Ecosystems

Revisiting National Systems of Innovation in the UN SDGs Era (2016–2026)

Carlos Freire-Gibb
MacEwan University, Triffo School of Business, Canada, carlos.freiregibb@macewan.ca

Claudia De Fuentes
Saint Mary's University, Sobey School of Business, Canada, claudia.defuentes@smu.ca

Jesper L. Christensen
Aalborg University, Aalborg University Business School, Denmark, jlc@business.aau.dk

Louise Earl
University of Ottawa and Saint Mary's University, Canada, learl@uottawa.ca

1. Introduction:

The Sustainable Development Goals (SDGs) Report 2025 declared a "global development emergency": only 35% of SDG targets are on track or making moderate progress, and 18% have regressed below the 2015 baseline (United Nations, 2025, p. 2). The challenges include: (a) extreme poverty affecting more than 800 million people; (b) climate crisis marked by record-breaking high temperatures; (c) 120 million people forcibly removed from their homes amid deteriorating peace and security; (d) mounting economic and financial crises; and (e) accelerating environmental degradation.

The SDGs themselves call for integrated, multi-stakeholder strategies that address the complex interdependencies between social, economic, and environmental goals, in other words systematic and holistic approaches. The innovation systems (IS) framework offers a particularly appropriate analytical and policy toolkit for this purpose. By examining the interactions among actors, institutions, and knowledge flows that drive transformative change, the IS framework provides insights into how countries can accelerate progress toward achieving the SDGs through coordinated interventions that enhance innovation capacity, strengthen institutional arrangements, and mobilize resources effectively. All in all, the SDGs challenges require complex systemic change and cannot be solved by technological fixes alone. The SDGs/Agenda 2030 formally began on January 1, 2016 (United Nations, 2015). Ten years on, this is a timely moment to assess progress. Although the SDGs initially received broad support, political discourse has since shifted, with growing resistance driven in part by misinformation and disinformation (Sa'ad Abdullahi & Pindiga, 2023).

In this situation, the National System of Innovation (NSI) framework can be useful for three reasons: first, because nation-states remain central actors in shaping innovation outcomes; second, because national governments bear primary responsibility for implementing the SDGs; and third because addressing complex challenges requires participation of multiple actors driving systemic change.

The paper reviews the evolution of the NSI framework, recent renewed interest in national innovation coordination, and its application to Canada's sustainability, resilience, and sovereignty challenges. It concludes with implications for research and policy, emphasizing NSI relationships and lessons from the first decade of SDG implementation (2016–2026).

2. Literature Review

The literature shows NSI approaches can advance SDGs via interconnected mechanisms. Across 130 countries, knowledge-based capabilities positively affect SDG outcomes (Li et al., 2023); data from 143 countries (2011–2023) estimate a 1-point Global Innovation Index rise correlates with a 0.486-point SDG Index increase, confirming innovation's role (Le et al., 2025). Pathways include technology, collaboration, and systemic change (Ramirez et al., 2019).

Key NSI components include R&D, university-industry-government linkages, policy frameworks, and capacity-building (Weerasinghe & Gunawardena, 2024); however, their effectiveness is context-dependent, moderated by development, institutions, and sector interactions. Gains are strongest in lower-middle-income countries (Le et al., 2025); while high-income countries need deeper transformation (Christensen et al., 2021; Novillo-Villegas et al., 2025). Nevertheless, success requires strong institutions, government support for networks, and aligned capacity-building (Chaparro-Banegas et al., 2024).

2.1 Key contributions and evolution of the NSI

As early as the mid-1990s, Metcalfe[1] (1994, 1995) was publishing papers on innovation policy from an evolutionary/system perspective; Nelson had even earlier offered a view on how and why the direction and prioritization of technological change matter to addressing societal challenges. His book *The Moon and the Ghetto* (1977) addresses a central paradox of modern economies: societies capable of extraordinary technological achievements often struggle to address persistent social problems such as poverty and inequality. Nelson argues that this paradox arises due to how societies pursue technological endeavors and how they approach social challenges. Large technological projects succeed because they mobilize coordinated funding, clear objectives, performance metrics, and aligned incentives across organizations. Social problems, by contrast, are addressed through fragmented responsibilities, weak incentives, and poor feedback mechanisms. In "The Moon and the Ghetto Revisited" (2011), Nelson emphasizes that these institutional failures remain largely unresolved, limiting the scalability and effectiveness of social innovations. In related work (e.g. Mowery et al., 2010), he proposed new types of policy models for addressing problems like climate action. Eventually, he formulated a pertinent question: "can we reorient our innovation systems so that the advances we get are better directed to meeting society's most pressing needs?" (Nelson, 2011, p.682)[2].

While many science, and technology scholars in the decades following the Second World War emphasized the contributions of military technologies to civilian technological advances (Gummett & Reppy, 1988), other scholars of the same period argued that technological progress also originated from civilian domains. For instance, Lundvall (1988) proposed: a "welfare-industrial complex oriented towards the fulfillment of social needs in relation to energy, housing, environment, transport, and the health service [which could] be as effective as warfare-industrial complexes in provoking new technology" (p. 366).

[1] 2025 saw the loss of some of the greatest scholars within the field of economic and technical change, including F. Scherer, S. Metcalfe, and R. Nelson.

[2] Nelson joined the GlobeLics initiative, started by Lundvall, which is aimed at enhancing higher (PhD) education in developing countries, much in line with the thoughts behind The Moon and the Ghetto.

Christopher Freeman was another key scholar in the development of innovation system thinking relevant to the SDGs. His book The Economics of Hope (Freeman, 1992) emphasizes the importance of directionality in technological change, opposing dysfunctional predictions based on modelling from Meadows and colleagues at MIT in the early 1970s, and arguing that innovation holds potential for solving societal challenges if promoted wisely. He emphasizes the role of public investment, regulation, and long-term strategy in steering innovation toward socially beneficial outcomes.

2.2 Calls for NSI to increase focus on issues related to UN SDGs

Many innovation scholars increasingly stress the need to respond to urgent calls for action on sustainability transition policies (Chaminade, 2020; Christensen et al., 2021; Andersen et al., 2023; Lema & Perez, 2024). The IS framework speaks directly to this agenda: it has been applied to sustainability transformation (Schlaile et al., 2017), the engagement of excluded communities and civil society (Earl et al., 2023), capacity to achieve the UN SDGs in low and middle-income countries (Adenle et al., 2023) and high-income countries (Cavalli & McGahan, 2024), and the SDGs concerning economic inequality and climate action (Lundvall, 2024).

Innovation system approaches to policy gained attention in the early 2000s (Christensen & Fagerberg, 2021) but have since waned in popularity. Perhaps the field's most popular contribution to advancing innovation policy and addressing the UN SDGs is Mazzucato's (2018) concept of mission-oriented policy. In articulating this idea, Mariana Mazzucato builds on the NSI literature but brings it back to its more active political roots.

In her analysis of the contributions of the NSI framework, Mazzucato (2011) pointed to its ability to improve understanding of national innovation policy, noting that NSI showed that "it is not the quantity of R&D that matters but how it is distributed throughout an economy, and often the crucial role of the state in achieving this" (p. 65). In other words, while the NSI framework describes how innovation is developed, Mazzucato goes further, asking what innovation should be designed to do, and who should benefit. Her main argument is "that the state can be far more proactive in spurring industrial innovation at the forefront of knowledge than is currently understood by policy makers" (p.70).

Mazzucato (2025, 2026) has also called for reimagining SDG financing by moving beyond gap-filling exercises toward actively shaping financial systems to support transformative change. These contributions collectively establish mission-oriented policies as viable mechanisms for accelerating SDG progress through purposeful direction of innovation and investment.

This approach emphasizes the active role of the state in shaping markets through coordinated public investment and strategic policy direction (Mazzucato, 2018). Traditional innovation system approaches, rooted in the NSI framework, typically focus on horizontal policies that address structural weaknesses, such as limited absorptive capacity, weak linkages between actors, or insufficient knowledge flows. In contrast, mission-oriented policies begin with explicit, societally relevant goals and mobilize multiple policy instruments to steer innovation toward desired outcomes (Larrue, 2021). Rather than merely fixing systemic failures, mission-oriented approaches seek to actively create and shape markets in alignment with public priorities.

One potential issue for the effectiveness of this approach is the increasing power of corporations and the decreasing role of national governments (Mazzucato, 2025). In fact, the role of national

governments in achieving the UN SDGs has experienced competition of various types from the private sector. Genuine contributions are observed in specific contexts, such as private firms, hybrid organizations like B Corps, and companies with robust stakeholder governance mechanisms, where accountability structures align incentives with long-term sustainability outcomes rather than short-term reputational gains (Diez Busto et al., 2021) , cooperatives or employees ownership trusts (MacLeod & Johnson, 2026). However, in other cases, corporations, under the disguise of Corporate Social Responsibility (CSR) or Environment, Social, and Governance (ESG) initiatives, have been accused of superficially co-opting the UN SDGs rather than substantively advancing them (Spry & France, 2025). Empirical evidence largely supports this critique, revealing widespread "SDG-washing" characterized by symbolic actions, selective disclosure, and a decoupling of communications from real performance (Heras-Saizarbitoria et al., 2021). Studies indicate that most large corporations, particularly publicly traded firms, engage in performative use of SDG iconography and cherry-picked goals to manage impressions without implementing meaningful changes (Heras-Saizarbitoria et al., 2021).

The following section introduces the idea of the potential return of a NSI framework in the context of current geopolitical challenges.

2.3 A return of National System of Innovation (NSI)?

One of the reasons watered-down SDG efforts and SDG-related greenwashing have occurred has been the declining role of the national governments and their lack of innovation potential, along with multinational corporations seeing financial benefit in suggesting that they are taking action towards critical issues. However, if we return to the NSI concept as originally articulated, the role of the nation-state was very clear (Lundvall, 1992).

Historically, national governments have been essential to innovation development (Freeman, 1987, 1995). The nation-state remains the dominant level at which innovation policy is designed, resourced, and legitimated. The early concept of the NSI related to:

> *"... a new spirit of what might be called "technonationalism" in the air, combining a strong belief that the technological capabilities of a nation's firms are a key source of their competitive prowess, with a belief that these capabilities are in a sense national, and can be built by national action."* (Nelson & Rosenberg, 1993, p. 12)

However, subsequent global trends contributed to shifting the focus of innovation system research away from the "national." Following the end of the Cold War, accelerated globalization and market liberalization led to growing skepticism about the role of national governments, per se, in economic coordination (Fukuyama, 1989).

Various innovation scholars agreed that "the *'national'* system of innovation concept has run its course and now provides only decreasing returns" (Sharif, 2006).

Globalization challenged the NSI framework by weakening nationally rooted innovation structures and creating a risk that firm-level gains from participation in the global value chain would not translate into sustained national knowledge development or upgrading (Lundvall, 2016). During the late 1990s and early 2000s, research on innovation fragmented into complementary and sometimes competing perspectives, including Regional Innovation Systems (Cooke et al., 1998), Sectoral Systems of Innovation (Malerba, 2002), and Socio-Technical

Transitions (Geels, 2004). Later, the more firm-centric concept of "entrepreneurial ecosystems" nearly eclipsed the broader "innovation system" framework in both academia and public policy (Spigel & Stam, 2018). This diversity of IS approaches resulted in confusion and blurred boundaries (Rakas & Hain, 2019). Perhaps more importantly, while these approaches generated valuable insights, they may have weakened attention to the role of national-level coordination and governance in innovation (e.g. Holbrook & Salazar, 2004; Wolfe & Lucas, 2004).

The Covid-19 pandemic contributed to mark a turning point that reversed decades of declining attention to national-level innovation governance. Recent evidence confirms a "structural break around 2020, characterized by accelerated policy activity and the emergence of 'new industrial policies' motivated by supply chain resilience, national security, and geopolitical concerns" (Evenett et al., 2025, p. 2).

This shift has restored the nation-state to analytical prominence and reopened questions about how national industrial and innovation policy operate under conditions of globalized production and strategic risk (Juhász et al., 2024; Breznitz & Gingrich, 2025).

3. Methodology

This paper adopts a conceptual, narrative literature-synthesis approach, drawing on the National Systems of Innovation (NSI) tradition and the broader innovation-systems and mission-oriented policy literatures to reassess their relevance for the UN SDGs a decade into implementation of the 2030 Agenda. This synthesis is complemented by a short bibliometric-style trend analysis intended to track shifts in scholarly and public discourse around national-level innovation coordination. We also analyze Google Ngram Viewer data for the term "industrial policy" in English-language publications (data downloaded early 2026) alongside Google Trends search-interest data for the terms "industrial policy," "innovation systems," and "innovation policy." These discourse-trend data are used descriptively, alongside secondary sources, to contextualize the discussion of Canada's National System of Innovation presented below.

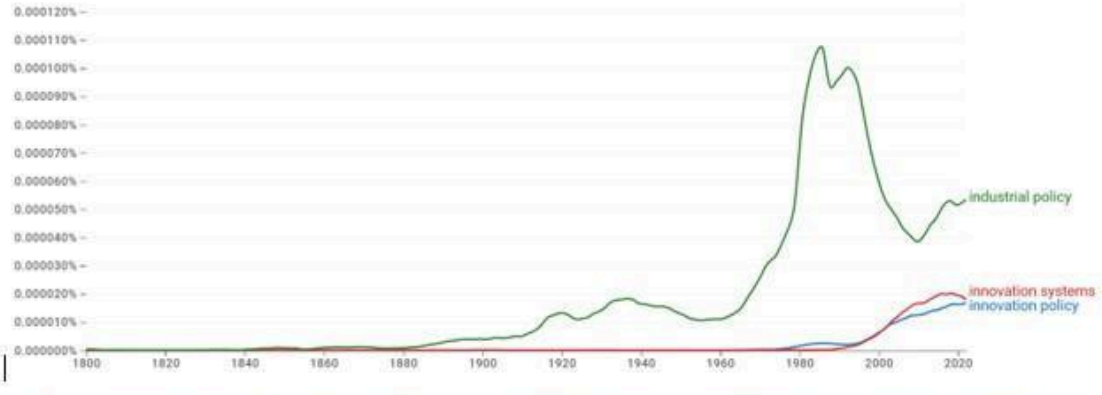
4. Analysis

4.1 Discourse trends: industrial policy, innovation systems, and innovation policy

As illustrated by long-term trends in search interest, concepts such as "innovation system" and "innovation policy" have gained visibility since the late 1990s and early 2000s (Christensen & Fagerberg, 2021), reflecting their growing use in academic and policy debates. This pattern suggests a gradual shift away from narrow, firm-level or R&D-focused perspectives toward more systemic views that emphasize institutions, coordination, and multi-level interactions across national, regional, and sectoral innovation systems.

An analysis of Google Ngram Viewer data downloaded January 2026 reveals a significant decline in the usage of the term "industrial policy" in English-language publications from the mid-1990s until approximately 2010. Since then, however, the term has experienced some resurgence. This resurgence is notably more pronounced and abrupt than the more gradual trends observed for related concepts like "innovation systems" or "innovation policy," suggesting a broader scholarly and policy re-engagement with state-led economic coordination.

Figure 1. Revisiting National Systems of Innovation in the UN SDGs Era (2016–2026)



Notably, while Google Trends data for the search terms "industrial policy," "innovation systems," and "innovation policy" shows no sustained increase in search interest in recent years, it also shows that a distinct spike occurred in mid-July 2025. This peak, likely catalyzed by significant policy announcements from the Trump administration, including unprecedented tariffs, trade policies, and hostile geopolitical posturing toward many nations, prompted explosive growth for all three terms, with "industrial policy" leading.

Figure 2. Revisiting National Systems of Innovation in the UN SDGs Era (2016–2026)



Collectively, these trends indicate that contemporary economic policy debates are increasingly characterized by a fusion of systemic innovation perspectives with more direct attention to "new" industrial policy instruments. This convergence raises critical questions for governance and coordination, particularly regarding the integration of innovation policy frameworks, traditional industrial policy tools, and mission-oriented approaches for national economic development and resilience. Perhaps, given these conditions, a "new" NSI will arise.

4.2 The case of Canada

Canada's innovation system is characterized by strong inputs but weak outputs, the innovation paradox which remains at the core of its economic and societal challenges (Gellatly & Gu, 2024;

Hewitt, 2024). This may partially result from the pronounced dependency on the United States which has long impacted Canada's economic and innovation systems. This structural reliance has historically afforded US entities substantial influence over both R&D and commercialization in Canada (Atkinson & Zhang, 2024; Gold, 2025). This dependence was manageable when trade relations were stable (Stanley, 2006); however, recent aggressive trade policies adopted by the US have exposed serious vulnerabilities in the Canadian economy, negatively impacting investment, the job market, and overall economic growth (Tombe, 2025). President Trump's expression of an intent to take Canada "by economic force" (Louis, 2025) and trade disputes will influence business decisions.

The 2025 Federal Budget highlights the need to respond to this shift: "A new era of disruption demands (…) a new economic foundation built on resilience, sovereignty, and innovation" (Department of Finance Canada, 2025, p. 2). Canada may have the components of the strong innovation system needed to support such a transformation, including an ample knowledge base and strong organizations and institutions, but improved systemic orchestration is needed among these components. Some innovation policy experts even claim Canada does not have a proper functioning NSI (Zhang, 2025).

Canada's federal government currently prioritizes SDG 3 (Good Health and Well-Being), SDG 5 (Gender Equality), SDG 8 (Decent Work and Economic Growth), SDG 14 (Life Below Water), and SDG 17 (Partnerships for the Goals) (Government of Canada, 2025). In light of the major economic, social, and national security challenges Canada is facing, however, Tombe (2025) argues that "In this environment, policies that strengthen the economic foundation must take priority. Other goals, however worthy, may need to wait." While Canada has so far avoided some of the worst-case outcomes associated with rising geopolitical and economic tensions, it remains possible that these pressures may require a reassessment and more policy attention to other SDGs.

There is a need for further research to address the relative weakness of Canada's innovation system and advance the country's progress toward the SDGs. Research in this direction would benefit from incorporating the NSI framework (Lundvall, 1992; Niosi, 2000; Chaminade et al., 2018), which provides a systemic view of innovation at the national level. This framework could help to generate urgently needed knowledge to support the strengthening of Canada's national innovation capacity by providing a system-wide analysis of Canada's NSI in a broad sense[3], going beyond examining R&D, high-tech sectors, and patents to examine the relationships among key actors within Canada's NSI.

As articulated by Canada's Prime Minister Carney (2026), strengthening national innovation capacity in these turbulent times should not be understood as a move to create "isolated fortresses". Recent geopolitical developments suggest that the advancement of a NSI does not

[3]Niosi (2000), working with other innovation scholars, published the volume “Canada’s National System of Innovation”. Quoting the innovation literature, he distinguished between “the narrow definition [of NSI] (encompassing only the institutions active in R&D and the public regulatory agencies) and the broad sense (also including supporting private institutions, such as banks, and public ones, such as government infrastructure and education systems)” (p. 5). Niosi acknowledged that his work focused on the narrow sense.

imply withdrawal from global networks, but rather a reconfiguration of international engagement through diversification of partnerships and more balanced interdependencies. From this perspective, analyzing the relational structure of Canada's NSI is particularly important, as it helps identify coordination failures, institutional bottlenecks, and areas where domestic capacity could be strengthened through more resilient and diversified forms of collaboration (Freire-Gibb et al., 2026).

5. Concluding Remarks

The persistent lack of progress toward the UN Sustainable Development Goals demonstrates that fragmented policy responses are no longer sufficient. The SDGs demand coordinated, system-wide action that aligns technological change with clearly defined social priorities. This paper has argued that revisiting the National Systems of Innovation (NSI) framework provides a timely and necessary foundation for meeting this challenge.

Historically, NSI scholarship emphasized that innovation outcomes are shaped by institutions, public policy, and coordination, not by markets and firms alone. These insights remain directly relevant to the SDGs, which require directionality, collective action, and long-term commitment to achieve. Empirical evidence shows that innovation systems can accelerate progress toward certain SDGs, but also that poorly governed innovation can undermine others. This underscores the need for innovation policy that goes beyond R&D intensity and commercialization to address systemic governance and societal purpose.

Recent developments, including geopolitical tensions and supply-chain disruptions, have generated renewed interest in industrial policy and led national governments to embark on innovation policy agendas. In this context, mission-oriented approaches can be understood not as a break from NSI thinking, but as a reinforcement of its original political and societal foundations, providing practical tools to steer innovation toward sustainability goals.

The Canadian case illustrates both the risks of weak system coordination and the opportunities offered by a broader NSI perspective. While Canada possesses strong innovation inputs, persistent coordination failures limit its ability to translate these strengths into sustainable outcomes, leading to what has been termed Canada's innovation paradox. Addressing this gap requires renewed attention to the structure and quality of relationships across the NSI, including horizontal and vertical approaches within public institutions, finance, education, industry, national security and civil society.

Revisiting the NSI framework is therefore not only an academic exercise, but a policy imperative. Empowering innovation systems to advance the SDGs requires restoring the role of the state as a coordinating and directional actor, strengthening institutional linkages, and aligning innovation with societal missions. In an era of overlapping sustainability and geopolitical challenges, a renewed NSI framework offers a coherent and actionable pathway for advancing the UN SDGs.

6. References

Adenle, A. A., De Steur, H., Mwongera, C., Rola-Rubzen, F., de Barcellos, M. D., Vivanco, D. F., et al. (2023). Global UN 2030 agenda: How can science, technology and innovation accelerate the achievement of

Sustainable Development Goals for all? PLOS Sustainability and Transformation, 2(10), e0000085. https://doi.org/10.1371/journal.pstr.0000085

Andersen, A. D., Geels, F. W., Coenen, L., Hanson, J., Korsnes, M., Linnerud, K., & Wiebe, K. (2023). Faster, broader, and deeper! Suggested directions for research on net-zero transitions. Oxford Open Energy, 2, oiad007. https://doi.org/10.1093/ooenergy/oiad007

Atkinson, R., & Zhang, L. (2024). Assessing Canadian innovation, productivity, and competitiveness. Information Technology and Innovation Foundation. https://itif.org/publications/2024/04/29/assessing-canadian-innovation-productivity-and-competitiveness/

Breznitz, D., & Gingrich, J. (2025). Industrial policy revisited. Annual Review of Political Science, 28, 329–350. https://doi.org/10.1146/annurev-polisci-033123-020253

Carney, M. (2026, January 20). Principled and pragmatic: Canada's path. Speech at the World Economic Forum Annual Meeting. https://www.pm.gc.ca/en/news/speeches/2026/01/20/principled-and-pragmatic-canadas-path-prime-minister-carney-addresses

Cavalli, G., & McGahan, A. M. (2024). Opening innovation to address grand challenges. In H. Chesbrough et al. (Eds.), The Oxford handbook of open innovation. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780192899798.013.34

Chaminade, C. (2020). Innovation for what? Unpacking the role of innovation for weak and strong sustainability. Journal of Sustainability Research, 2(1).

Chaminade, C., Lundvall, B.-Å., & Haneef, S. (2018). *Advanced introduction to national innovation systems*. Edward Elgar Publishing.

Chaparro-Banegas, N., Ibañez Escribano, A. M., Mas-Tur, A., & Roig-Tierno, N. (2024). Innovation facilitators and sustainable development: A country comparative approach. *Environment, Development and Sustainability*, *26*, 8467–8495. **https://doi.org/10.1007/s10668-023-03055-w**

Christensen, J. L., & Fagerberg, J. (2021). The emergence of innovation policy as a field: The international context and the Danish experience. In Globalisation, New and Emerging Technologies, and Sustainable Development (pp. 13-32). Routledge.

Christensen, J. L., Gregersen, B., Holm, J. R., & Lorenz, E. N. (2021). Globalisation, new and emerging technologies, and sustainable development. Routledge.

Cooke, P., Uranga, M. G., & Etxebarria, G. (1998). Regional systems of innovation: An evolutionary perspective. Environment and Planning A, 30(9), 1563–1584. https://doi.org/10.1068/a301563

Department of Finance Canada. (2025). Budget 2025: Canada strong. Government of Canada. https://budget.canada.ca/2025/home-accueil-en.html

Diez-Busto, E., Sanchez-Ruiz, L., & Fernandez-Laviada, A. (2021). The B Corp movement: A systematic literature review. *Sustainability*, *13*(5), 2508.

Earl, L., De Fuentes, C., Kinder, J., & Schillo, R. (2023). Inclusive innovation and how it can be measured in developed and developing countries. In Handbook of innovation indicators and measurement (pp. 297–322). Edward Elgar Publishing.

Evenett, S., Jakubik, A., Kim, J., Martín, F., Pienknagura, S., Ruta, M., Baquie, S., Huang, Y., & Parente, R. M. (2025). Industrial policy since the great financial crisis (IMF Working Paper No. WP/25/222). International Monetary Fund.

Freeman, C. (1987). Technology policy and economic performance: Lessons from Japan. Pinter Publishers.

Freeman, C. (1992). The economics of hope: Essays on technical change, economic growth and the environment. Pinter Publishers.

Freeman, C. (1995). The national system of innovation in historical perspective. Cambridge Journal of Economics, 19(1), 5–24. https://doi.org/10.1093/oxfordjournals.cje.a035309

Freire-Gibb, C., De Fuentes, C., Christensen, J., & Earl, L. (2026). Empowering innovation systems to advance the United Nations' Sustainable Development Goals: An Editorial. Canadian Journal of Administrative Sciences, 43(2), e70069.

Fukuyama, F. (1989). The End of History? The National Interest, 16, 3–18. http://www.jstor.org/stable/24027184

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. Research Policy, 33(6–7), 897–920. https://doi.org/10.1016/j.respol.2004.01.015

Gellatly, G., & Gu, W. (2024, July). Understanding Canada's innovation paradox: Exploring linkages between innovation, technology adoption and productivity. Economic and Social Reports, 4(7). Statistics Canada. https://doi.org/10.25318/36280001202400700002-eng

Gold, E. R. (2025, December 23). Canada's innovation policy: Designed in Ottawa, owned in America. The Globe and Mail. https://www.theglobeandmail.com/business/commentary/article-canadas-innovation-policy-designed-in-ottawa-owned-in-america/

Government of Canada. (2025, November 3). Taking action together – Canada's 2025 annual report on the 2030 Agenda and the Sustainable Development Goals. Employment and Social Development Canada. Retrieved January 16, 2026, from https://www.canada.ca/en/employment-social-development/programs/agenda-2030/2025-annual-report-sdg.html

Gummett, P., & Reppy, J. (Eds.). (1988). The relations between defence and civil technologies. Kluwer Academic Publishers.

Heras-Saizarbitoria, I., Urbieta, L., & Boiral, O. (2021). Organizations' engagement with sustainable development goals: From cherry-picking to SDG-washing? Corporate Social Responsibility and Environmental Management.

Hewitt, T. (2024, October 21). Solving Canada's innovation paradox. The Hill Times. https://www.hilltimes.com/story/2024/10/21/solving-canadas-innovation-paradox/438073/

Holbrook, A., & Salazar, M. (2004). Regional innovation systems within a federation: Do national policies affect all regions equally? Innovation, 6(1), 50–64. https://doi.org/10.5172/impp.2004.6.1.50

Juhász, R., Lane, N., & Rodrik, D. (2024). The new economics of industrial policy. Annual Review of Economics, 16, 213–242. https://doi.org/10.1146/annurev-economics-081023-024638

Larrue, P. (2021). The design and implementation of mission-oriented innovation policies (OECD Science, Technology and Industry Policy Papers). OECD Publishing.

Le, H. N., Dang, M. N., Ho, P. U., Tran, N. H. N., Tran, T. A. V., Nguyen, P. H., & Trinh, M. Q. (2025). The more, the merrier? Innovation-led sustainable development. Sustainable Development, 1-29. https://doi.org/10.1002/sd.70292

Lema, R., & Perez, C. (2024). The green transformation as a new direction for techno-economic development. Innovation and Development.

Li, X., Wu, T., Zhang, H.-J., & Yang, D.-Y. (2023). National innovation systems and the achievement of sustainable development goals: Effect of knowledge-based dynamic capability. Journal of Innovation & Knowledge, 8(1), 100310. https://doi.org/10.1016/j.jik.2023.100310

Louis, S. (2025, January 8). How far could Trump go using "economic force" to try and annex Canada? Financial Post. https://financialpost.com/news/trump-using-economic-force-annex-canada

Lundvall, B.-Å. (1988). Innovation as an interactive process: From user–producer interaction to the national system of innovation. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg, & L. Soete (Eds.), Technical change and economic theory (pp. 349–369). Pinter Publishers.

Lundvall, B.-Å. (Ed.). (1992). National systems of innovation: Towards a theory of innovation and interactive learning. Pinter Publishers.

Lundvall, B.-Å. (2016). The learning economy and the economics of hope. Anthem Press.

Lundvall, B.-Å. (2024). Transformative innovation policy: Lessons from the innovation system literature. Innovation and Development, 14(2), 297–314.

MacLeod, P., & Johnson, R. (2026). *Democracy's Second Act: Why Politics Needs the Public*. Aevo UTP.

Malerba, F. (2002). Sectoral systems of innovation and production. Research Policy, 31(2), 247–264. https://doi.org/10.1016/S0048-7333(01)00139-1

Mazzucato, M. (2011). The entrepreneurial state. Demos.

Mazzucato, M. (2018). Mission-oriented innovation policies: Challenges and opportunities. Industrial and Corporate Change, 27(5), 803–815.

Mazzucato, M. (2025). Mission-oriented policy: From fixing markets to shaping markets and debunking myths about the state. Cambridge Journal of Regions, Economy and Society, Article rsaf024. https://doi.org/10.1093/cjres/rsaf024

Mazzucato, M. (2026). Salud para todos: Más que una concesión, un imperativo económico. *Empresa Global*. https://www.empresaglobal.es/EGAFI/contenido/2558501/1633772/salud-para-todos-mas-que-una-concesion-un-imperativo-economico.html

Metcalfe, J. S. (1994). Evolutionary economics and technology policy. The Economic Journal, 104(425), 931–944.

Metcalfe, J. S. (1995). Technology systems and technology policy in an evolutionary framework. Cambridge Journal of Economics, 19(1), 25–46.

Mowery, D. C., Nelson, R. R., & Martin, B. R. (2010). Technology policy and global warming: Why new policy models are needed (or why putting new wine in old bottles won't work). Research Policy, 39(8), 1011-1023.

Nelson, R. R. (1977). The moon and the ghetto: An essay on public policy analysis. W. W. Norton.

Nelson, R. R. (2011). The moon and the ghetto revisited. Science and Public Policy, 38(9), 681–690.

Nelson, R. R., & Rosenberg, N. (1993). Technical innovation and national systems. In R. R. Nelson (Ed.), National innovation systems: A comparative analysis (pp. 3–21). Oxford University Press.

Nicolò, G., Andrades‐Peña, F. J., Ferullo, D., & Martinez‐Martinez, D. (2023). Online sustainable development goals disclosure: A comparative study in Italian and Spanish local governments. Business Ethics, the Environment & Responsibility, 32(4), 1490-1505.

Niosi, J. (2000). Canada's national system of innovation. McGill–Queen's University Press.

Novillo-Villegas, S., Tulcanaza-Prieto, A. B., Chantera, A. X., & Chimbo, C. (2025). Exploring a sustainable pathway towards enhancing national innovation capacity from an empirical analysis. Sustainability, 17(15), 6922. https://doi.org/10.3390/su17156922

Rakas, M., & Hain, D. S. (2019). The state of innovation system research: What happens beneath the surface? Research Policy, 48(9), 103787.

Ramirez, M., Romero, O., Schot, J., & Arroyave, F. J. (2019). Mobilizing the transformative power of the research system for achieving the sustainable development goals (SPRU Working Paper Series No. 2019-13). University of Sussex.

Sa'ad Abdullahi, B., & Pindiga, H. I. (2023). Tracking the diffusion of disinformation on the SDGs across social media platforms. In J. Servaes & M. J. Yusha'u (Eds.), SDG18 communication for all (Vol. 2). Palgrave Macmillan. https://doi.org/10.1007/978-3-031-19459-7_6

Schlaile, M. P., Urmetzer, S., Blok, V., Andersen, A. D., Timmermans, J., Mueller, M., Fagerberg, J., & Pyka, A. (2017). Innovation systems for transformations towards sustainability? Taking the normative dimension seriously. *Sustainability, 9*(12), 2253.

Sharif, N. (2006). Emergence and development of the national innovation systems concept. Research Policy, 35(5), 745–766.

Spigel, B., & Stam, E. (2018). Entrepreneurial ecosystems. In SAGE handbook of entrepreneurship and small business. Sage Publications.

Spry, A., & France, C. (2025). Washing the Sustainable Development Goals: Lessons from the greenwashing and woke washing literature. In The Elgar companion to marketing and the Sustainable Development Goals (pp. 12–26). Edward Elgar Publishing.

Stanley, G. (2006). What's wrong with Canada's innovation? Policy Options, Dec06-Jan07, 68–71. https://policyoptions.irpp.org/wp-content/uploads/assets/po/afghanistan2/stanley.pdf

Tombe, T. (2025, December 11). *Get ready for a troubling new era for the Canadian economy.* The Hub. https://thehub.ca/2025/12/11/get-ready-for-a-troubling-new-era-for-the-canadian-economy/

United Nations. (2015). Transforming our world: The 2030 agenda for sustainable development. United Nations.

United Nations. (2025). The Sustainable Development Goals report 2025. https://unstats.un.org/sdgs/report/2025/The-Sustainable-Development-Goals-Report-2025.pdf

Weerasinghe, R., & Gunawardena, K. S. L. (2024). Unveiling university networks aligning with SDGs: A social network analysis of the national innovation system of Sri Lanka. *Journal of Lifestyle and SDGs Review, 5*(1), e02967. https://doi.org/10.47172/2965-730X.SDGsReview.v5.n01.pe02967

Wolfe, D. A., & Lucas, M. (Eds.). (2004). *Clusters in a cold climate: Innovation dynamics in a diverse economy.* McGill-Queen's University Press.

Zhang, L. (2025, July 7). Canada doesn't have an innovation system: It has 134 programs. *Information Technology and Innovation Foundation.* https://itif.org/publications/2025/07/07/canada-doesnt-have-innovation-system-it-has-134-programs/

Innovation Ecosystems and the Cluster as a Unit of Analysis: A Systematic Review with Perspectives for Latin American Industrial Clusters

Carlos Mario Tabares Ramos
Universidad Nacional de Colombia, cmtabaresr@unal.edu.co

1. Introduction

Validating the appropriate use of strategies aimed at the continuous improvement of organizations opens possibilities for growth and for strengthening processes that favor better practices (Granstrand & Holgersson, 2020), thereby enhancing value creation and the performance of the initiatives undertaken (Yang, Yang, & Guo, 2024). Within this framework, various approaches have been developed toward building scenarios that sustain, over time, those firms seeking to generate added value, with innovation understood as a transversal feature that drives continuous improvement in market participation (Sun, Liu, & Huang, 2022). Investment in value generation and in meeting market needs should be a focus of research, provided that such investment does not drastically alter the firm's core mission (Peirone, Pereira, Leitão, & Nezghoda, 2024; Huang, Li, & Li, 2023). In this sense, the concept of the Innovation Ecosystem emerges as a strategic construct that fosters innovation through the involvement of actors who interact positively with one another, addressing emerging market needs (Wei, Ni, Zhang, & Duan, 2023; Carneiro, Isidro, & Criado, 2022).

Participation in Innovation Ecosystems enhances the acquisition of added value through the positioning that alliances and agreements between actors provide (Lee, 2020); in this regard, such alliances position small and medium sized organizations as relevant inflection points, given the nexus they establish for both internal and external value generation. The literature underscores the importance of State and academic involvement for the proper development of the ecosystem (Carneiro et al., 2022; Jalilian & Zanjirchi, 2023) and warns that the understanding of the concept may vary depending on the interests of each participating component (Ranga, Mroczkowski, & Araiso, 2017; Pellikka & Ali-Vehmas, 2016).

Several authors have validated the practicality of the concept in terms of the benefits it affords to participating organizations (Ferasso & Sztando, 2022; Zeng, Lo, & Chen, 2024); others regard innovation development as a key vector for administrative growth and market participation (Zheng, Huang, Qian, Xu, & Shen, 2022; Shih, Hu, & Chou, 2024; Darkwa, 2023; Antonelli, Brunori, Jawhar, Petruzzella, & Roma, 2020; Resende & Bravo, 2016), noting that the Innovation Ecosystem provides these benefits without necessarily entailing additional costs for firm-level innovation, provided the economic capacities of the organizational system are assessed beforehand (Kai, de Lima, & Benitez, 2024).

The relationships among State, academia, industry, and society fostered by the Innovation Ecosystem allow for a more balanced distribution of burdens and responsibilities (Zhao, Lyu, & Grimes, 2024; Glukhov, Lialina, Rozhkov, Vasiukova, & Kosolapov, 2016). This raises the need to weigh the returns owed to each participating actor, so that particular interests do not undermine the sound functioning of the ecosystem (Glukhov et al., 2016; Andersson & Lindlöf, 2023). Within this framework, open innovation models have emerged, allowing the participation of different actors, regardless of whether they share a common business core, while reducing the costs and risks associated with innovation through shared investment (Alkhazaleh, Mykoniatis, & Alahmer, 2022; Bańka et al., 2024).

Cooperation among entities with differing interests, oriented toward satisfying the needs of the market in which they participate, requires that value generation not produce conflicts among the bodies involved. The Innovation Ecosystem addresses this need by connecting the various institutional mandates without giving rise to conflicts of interest among participants.

This need to clarify the term Innovation Ecosystem, and to examine its applicability to business environments, is precisely what motivates the doctoral research from which this document originates. That research is being carried out within the PhD in Engineering, Industry and Organizations program at Universidad Nacional de Colombia, and is centered on the competitiveness of the metalworking cluster of Manizales, Colombia, with the cluster taken as its specific unit of analysis. The remainder of this document is organized as follows: Section 2 reviews the literature on the Innovation Ecosystem construct and its components; Section 3 describes the systematic review methodology applied; Section 4 presents the bibliometric and thematic findings, together with their discussion; and Section 5 sets out the concluding remarks and the next steps of the ongoing doctoral work.

2. Literature review

In this regard, Mercan and Göktaş (2011) note that the Innovation Ecosystem offers considerable potential, particularly in converting knowledge into added value for participating industries; although these industries depend primarily on contributions generated within their own environment, the ecosystem strengthens business competitiveness. Three key components and their potential applications are thus identified. Cluster development refers to the geographic concentration of firms, suppliers, and industries aimed at promoting innovation within their respective fields, encouraging the creation of new knowledge and technology that improves firms' market positioning (Martínez-Marín, Puello-Pereira, & Ovallos-Gazabon, 2020). University-industry collaboration comprises alliances between academic institutions and firms that strengthen Research and Development, enabling better application of technological and scientific advances according to the needs of the productive sector. Innovative culture is a crucial factor for the success of any Innovation Ecosystem; its adoption facilitates firms' commitment to innovation, ensuring an environment conducive to continuous and sustainable development. Some authors nonetheless caution against misusing the term “ecosystem,” warning against its

arbitrary application to collective phenomena that do not strictly correspond to the concept (Cuartas Torres & Marín Cardona, 2023).

Within the Latin American context, Martínez-Marín et al. (2020) have modeled cluster competitiveness through systems dynamics, offering a formal treatment of the cluster as a differentiated unit of analysis rather than a simple derivation of regional or sectoral studies. Cuartas Torres and Marín Cardona (2023) extend this line of reflection to entrepreneurship ecosystems from a practical and conceptual standpoint, cautioning that the ecosystem metaphor should not be applied indiscriminately to collective phenomena that do not meet its defining conditions of interdependence among heterogeneous actors. Taken together, these Latin American contributions and the broader international literature reviewed above provide the conceptual foundation on which the systematic review reported in this document was designed, and on which the doctoral project itself is being built.

3. Methodology

With the aim of clarifying the term Innovation Ecosystem and validating its application to industry, regardless of the specific business core involved and of the benefits it offers within the market in which the firm participates, a systematic literature review strategy was adopted, following the PRISMA methodology, which allows for the establishment of appropriate criteria for document selection through successive reductions and filters (Arango, Rincón, & Berrio, 2023; Haddaway, Page, Pritchard, & McGuinness, 2022).

The search equation applied, identically across both bibliographic resources, was as follows:

(Innovation) AND NOT (Animals OR Habitat OR Environment) AND (Ecosystem) AND ("Innovation Ecosystems" OR "Innovation network") AND (Industries) AND (Organization) AND (Cluster)

The search was conducted on October 31, 2024. Its application in Scopus yielded 267 records (2012 to 2024 period; 150 sources; annual growth rate of 34.64 percent), and in Web of Science, 157 records (2010 to 2024 period; 84 sources; annual growth rate of 26.2 percent), for a total of 424 identified documents. This initial pool was subjected to a two-stage deduplication process. First, 45 duplicate records shared between both databases were removed, identified through DOI matching and normalized-title matching. Second, 1 guest editorial was excluded for not constituting original research. The result was a total of 378 unique records, which constitute the final corpus included in this review.

The topical relevance of the corpus is guaranteed by the very design of the search equation, which requires, through the mandatory AND operator, the co-occurrence of the terms Industries, Organization, and Cluster alongside Innovation Ecosystems, thereby narrowing the scope of the search from its own formulation. The complete process was documented following the PRISMA

2020 reporting guidelines, and the bibliometric analysis was complemented with the Bibliometrix (Biblioshiny) tool.

4. Analysis of results

4.1 Overview of the corpus and thematic distribution

The Web of Science subset (n = 157) spans the 2010 to 2024 period across 84 sources, with 481 authors, an international co-authorship rate of 38.22 percent, 3.43 co-authors per document, and an average of 33.73 citations per document. The Scopus subset (n = 267) spans the 2012 to 2024 period across 150 sources, with 715 authors, an international co-authorship rate of 29.96 percent, and an average of 18.01 citations per document. Annual scientific production shows sustained growth from 2016 onward in both databases, peaking in 2023 (Web of Science) and 2024 (Scopus), confirming a growing and recent interest in the Innovation Ecosystem concept as applied to business environments. In both databases, the Management and Business categories concentrate the largest share of documents, consistent with the business-oriented focus of the search equation used. A complementary analysis of the deduplicated corpus (n = 378) allows for quantifying the presence of specific Innovation Ecosystem components beyond the general categories assigned by the databases. Table 1 presents this distribution.

Table 1. Thematic distribution of the deduplicated corpus (n = 378)

Component / theme	**% of corpus**
Governance and public-sector actors	44.2%
Sustainability / Sustainable Development Goals	25.1%
Evolutionary dynamics / lifecycle	23.5%
SMEs and entrepreneurship	20.9%
Digital transformation / Industry 4.0	14.0%
Value creation / co-creation	12.4%
Regional / urban ecosystems	6.6%
Health / biotechnology	6.6%
Knowledge management / technology transfer	6.1%
Triple / quadruple helix	5.6%
Clusters and agglomeration	**4.8%**

Note: a single document may address more than one theme; percentages do not sum to 100%. Source: own elaboration based on Bibliometrix/Biblioshiny output.

Table 1 shows that three thematic streams dominate literature on Innovation Ecosystems. The first, with the greatest relative weight (44.2 percent of the corpus), addresses the role of governance and public-sector actors, evidencing that the State does not act as a mere external regulator but as a structural component of the ecosystem (Carneiro et al., 2022). The second

stream, linked to sustainability and the Sustainable Development Goals (25.1 percent), reflects a recent shift in literature toward the articulation between innovation and environmental transition. The third, centered on the evolutionary dynamics of ecosystems (23.5 percent), suggests a growing consensus that Innovation Ecosystems are not static structures but systems that move through phases of emergence, consolidation, and eventual dissolution.

It is particularly noteworthy that the cluster and agglomeration component, the central unit of analysis for the doctoral research motivating this review, appears in only 4.8 percent of the reviewed corpus. This low representation is not confined to the Latin American context, already identified below as a geographic gap; it extends to the international literature as a whole, where the cluster as a specific organizational form of the Innovation Ecosystem receives less attention than other levels of analysis, such as the regional, urban, or sectoral. This dual gap, geographic and unit-of-analysis, reinforces the relevance of situated studies on specific industrial clusters, and suggests that their results could contribute not only contextualized evidence but also an underexplored case within the field's own conceptual architecture (Petchenko, Telnova, Yakushev, & Kuzminova, 2024).

4.2 Geographic distribution and highest-impact studies

The analysis of corresponding authors' countries evidences a marked geographic concentration of academic production: China leads by a wide margin, quadrupling its closest follower, followed by the United Kingdom and countries of continental Europe. No production from Latin American countries is identified among the top corresponding authors. This near-total absence of Latin American affiliations, confirmed in both Scopus and Web of Science, cannot be attributed to a methodological limitation of the search, given that the equation applied does not restrict geography or language. It follows, therefore, that this constitutes a genuine gap in academic output, consistent with what has been noted by Petchenko et al. (2024) regarding the scarcity of situated research in emerging contexts.

Consistent with the geographic concentration noted above, the most productive affiliations identified in the corpus are located at European and Asian universities, among them Tsinghua University, Vrije Universiteit Amsterdam, and Tampere University, with no Latin American institutions represented among the top ten most productive. Among the corpus items themselves, the most cited work, a 2010 paper by Adner and Kapoor, establishes that firm performance depends on the structure of upstream and downstream interdependence within the ecosystem, a framework taken up by later corpus items applying it to smart cities, agricultural innovation systems, and the external viability of ecosystem actors. These are reported here as descriptive findings of bibliometric analysis rather than as sources cited by the present authors and are accordingly not included in the reference list below.

5. Concluding remarks and next steps

Based on the systematic review conducted, distinct groups of interest are evidenced that promote and apply the Innovation Ecosystem as a generator of added value for industry; its application within the business environment directly drives the achievement of long-term sustainability objectives for the organizations involved. The establishment of appropriate keywords for this type of study directly contributes to the generation of useful material for future research, while also evidencing the field's recent consolidation in terms of publication output. A sustained increase in research associated with the Innovation Ecosystem is confirmed, validating the growing interest in clarifying its concept, application, and added value. Research interest in the term has emerged within the past fifteen years, with the earliest periods identified in Scopus and Web of Science dating to 2012 and 2010, respectively. A substantial gap is confirmed between research developed in the East, particularly China, and the limited academic interest in understanding this model within Latin American industrial culture, a gap that, as shown above, coexists with a second and largely independent one: the international underrepresentation of the cluster itself as a unit of analysis within the Innovation Ecosystem literature.

These two findings, taken together, constitute the point of departure for the doctoral research in progress, oriented toward examining the applicability of the Innovation Ecosystem framework to the metalworking cluster of Manizales, Colombia. As next steps, the doctoral project will advance along three complementary lines. First, it will articulate the Innovation Ecosystem framework with the postulates of General Systems Theory, in order to examine the applicability of its principles (totality, hierarchy, interdependence, homeostasis, entropy and negentropy, feedback, and equifinality) to the dynamics of the metalworking cluster. Second, it will gather primary information from the cluster's own actors (firms, academia, and public institutions) to empirically contrast the components identified in the literature, cluster development, university-industry collaboration, and innovative culture, against the reality of the Colombian case. Third, it will formulate a systemic competitiveness model applicable to industrial clusters in emerging economies, contributing to close the situated-knowledge gap identified in this review.

It is expected that these developments, informed by the training received within the NACLICS PhD Academy 2026, will provide evidence useful both to the academic community interested in Innovation Ecosystems and to the actors of the Manizales metalworking sector interested in strengthening their competitiveness.

6. References

Alka, T. A., Raman, R., & Suresh, M. (2024). Research trends in innovation ecosystem and circular economy. Discover Sustainability, 5(1). https://doi.org/10.1007/s43621-024-00535-5

Alkhazaleh, R., Mykoniatis, K., & Alahmer, A. (2022). The success of technology transfer in the Industry 4.0 era: A systematic literature review. Journal of Open Innovation: Technology, Market, and Complexity. https://doi.org/10.3390/joitmc8040202

Andersson, M., & Lindlöf, L. (2023). Your purpose or mine? Perspectives on data in innovation ecosystems. International Journal of Technology Management, 91(3-4), 219-238. https://doi.org/10.1504/IJTM.2022.10052665

Antonelli, A., Brunori, G., Jawhar, J., Petruzzella, D., & Roma, R. (2020). Innovation ecosystems for youth agrifood entrepreneurship in the Mediterranean region. New Medit, 19(4), 99-115. https://doi.org/10.30682/nm2004g

Arango, P. Z., Rincón, D. U., & Berrio, S. P. R. (2023). Relevancia, evolución y tendencias de la supervivencia empresarial. Una revisión de literatura en finanzas. Tendencias, 24(1), 252-278. https://doi.org/10.22267/RTEND.222302.223

Bańka, M., Salwin, M., Marczewska, M., Sychowicz, M., Kłos, J., & Rychlik, S. (2024). Startup accelerators: Research directions and gaps.

Carneiro, D. K. de O., Isidro, A., & Criado, J. I. (2022). Actors in the public sector innovation ecosystem: A comparative qualitative approach Brazil-Spain. New Trends in Qualitative Research, 14. https://doi.org/10.36367/ntqr.14.2022.e726

Cuartas Torres, C. A., & Marín Cardona, P. F. (2023). Ecosistemas de emprendimiento: hacia una reflexión práctica y conceptual. Revista Universidad y Empresa, 24(43), 1-38. https://doi.org/10.12804/revistas.urosario.edu.co/empresa/a.12044

Darkwa, I. (2023). Innovation: Actor heterogeneity and linkages in humanitarian innovation ecosystems. Innovation and Development. https://doi.org/10.1080/2157930X.2023.2234222

Ferasso, M., & Sztando, A. (2022). Innovation strategy, high-tech SMEs, and innovation ecosystems: A theoretical essay. International Journal of Enterprise Network Management, 13(4), 380-403. https://doi.org/10.1504/IJENM.2022.127620

Glukhov, V. V., Lialina, Z. I., Rozhkov, Y. V., Vasiukova, L. K., & Kosolapov, A. B. (2016). Household as a participant of an innovation ecosystem. International Review of Management and Marketing, 6(5), 61-66.

Granstrand, O., & Holgersson, M. (2020). Innovation ecosystems: A conceptual review and a new definition. Technovation. https://doi.org/10.1016/j.technovation.2019.102098

Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open Synthesis. Campbell Systematic Reviews, 18(2), e1230. https://doi.org/10.1002/CL2.1230

Huang, Y., Li, K., & Li, P. (2023). Innovation ecosystems and national talent competitiveness: A country-based comparison using fsQCA. Technological Forecasting and Social Change, 194. https://doi.org/10.1016/j.techfore.2023.122733

Jalilian, N., & Zanjirchi, S. M. (2023). Theoretical development of innovation ecosystem: A three-decade research landscape. International Journal of Innovation Science, 15(2), 224-244. https://doi.org/10.1108/IJIS-09-2021-0176

Kai, D. A., de Lima, E., & Benitez, G. B. (2024). A social cognitive perspective in innovation ecosystems: Understanding startups from ideation to consolidation in industry 4.0 era. Technological Forecasting and Social Change, 209. https://doi.org/10.1016/j.techfore.2024.123592

Lee, W.-I. (2020). Innovation ecosystem development strategy for activation of startup and technology commercialization in Daejeon. JP Journal of Heat and Mass Transfer, 2020(Special Issue 1), 13-22. https://doi.org/10.17654/HMSI120013

Martínez-Marín, S., Puello-Pereira, N., & Ovallos-Gazabon, D. (2020). Cluster competitiveness modeling: An approach with systems dynamics. Social Sciences, 9(2), 12. https://doi.org/10.3390/socsci9020012

Mercan, B., & Göktaş, D. (2011). Components of innovation ecosystems: A cross-country study. http://www.internationalresearchjournaloffinanceandeconomics.com

Pellikka, J., & Ali-Vehmas, T. (2016). Managing innovation ecosystems to create and capture value in ICT industries. Technology Innovation Management Review, 6(10), 17-24.

Peirone, D., Pereira, D. B., Leitão, J., & Nezghoda, O. (2024). The role of the agglomeration economy and innovation ecosystem in the process of competency development and growth of small and medium-sized enterprises. Administrative Sciences, 14(9). https://doi.org/10.3390/admsci14090222

Petchenko, M., Telnova, H., Yakushev, O., & Kuzminova, O. (2024). The evolution of the theory of innovation ecosystems in the context of strategisation. Economics Ecology Socium, 8(2), 85-97. https://doi.org/10.61954/2616-7107/2024.8.2-7

Ranga, M., Mroczkowski, T., & Araiso, T. (2017). University-industry cooperation and the transition to innovation ecosystems in Japan. Industry and Higher Education, 31(6), 373-387. https://doi.org/10.1177/0950422217738588

Resende, D. N., & Bravo, M. (2016). A top-down and bottom-up approach to improve regional innovation ecosystems in Portugal. Brazilian Journal of Operations & Production Management, 13(1), 86-93. https://doi.org/10.14488/BJOPM.2016.v13.n1.a10

Shih, T., Hu, M.-C., & Chou, J. C.-P. (2024). Navigating an emerging innovation ecosystem: A case study of fuel cell innovation in Taiwan. Asian Journal of Technology Innovation. https://doi.org/10.1080/19761597.2024.2352734

Sun, Z., Liu, W., & Huang, P. (2022). Construction of scientific and technological information service system from the perspective of innovation ecosystem. Journal of Modern Information, 42(7), 147-155. https://doi.org/10.3969/j.issn.1008-0821.2022.07.013

Wei, W., Ni, H., Zhang, H., & Duan, J. (2023). The niche and value creation mechanism of the innovation ecosystem of crowd innovation space: A multi-case study. Technology Analysis & Strategic Management. https://doi.org/10.1080/09537325.2023.2269267

Yang, S., Yang, J., & Guo, Y. (2024). Promoting green innovations for SMEs in emerging economies: Exploring the role of value supporters in innovation ecosystems. International Journal of Technology Management, 96(1-3), 35-63. https://doi.org/10.1504/IJTM.2024.140256

Zeng, L., Lo, C. K. Y., & Chen, Z. (2024). Fashion innovation through an innovation ecosystem, a research agenda. International Journal of Fashion Design, Technology and Education, 17(1), 62-75. https://doi.org/10.1080/17543266.2023.2247421

Zhao, Y., Lyu, L., & Grimes, S. (2024). An analytical framework for cross-border regional innovation ecosystems: The case of Shenzhen-Hong Kong cross-border region. Tijdschrift voor Economische en Sociale Geografie, 115(3), 402-417. https://doi.org/10.1111/tesg.12617

Zheng, J., Huang, Z., Qian, W., Xu, X., & Shen, L. (2022). Research on innovation efficiency in Zhejiang pharmaceutical industry from the perspective of innovation ecosystem. Chinese Journal of Modern Applied Pharmacy, 39(20), 2645-2651. https://doi.org/10.13748/j.cnki.issn1007-7693.2022.20.012

CHAPTER II.

II. Building Innovation Capabilities in Small and Open Economies

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

Marjorie Straw
Ardex Strategic Solutions, marjoriestraw@gmail.edu

Denise Ferguson
Entrepreneurial Development and Innovation, CARIRI, deniseferguson226@gmail.com

Tracey Broome,
University of the West Indies, Cave Hill Campus, tracey.broome@uwi.edu

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.

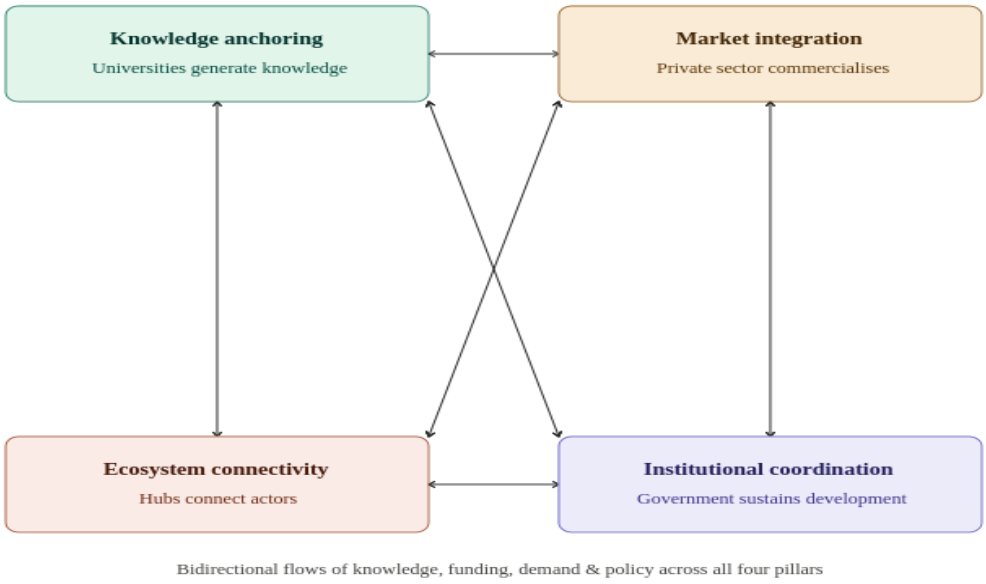
Pillar two, ecosystem connectivity, reflects the dependence of innovation ecosystems on sustained interaction among diverse actors. Innovation hubs facilitate network formation by creating structured environments where entrepreneurs, researchers, firms, policymakers, and investors interact regularly, 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

decisions are shaped by ecosystem connectivity just as government policy shapes what hubs and universities can do.

This networked design is consistent with a substantial body of peer-reviewed literature that has moved away from linear innovation models. The Triple Helix model of university-industry-government relations was developed explicitly to capture non-linear, reciprocal relationships among its three spheres, in which each institutional sphere can take the role of another rather than passing knowledge along a single chain (Etzkowitz & Leydesdorff, 2000). Carayannis and Campbell (2009) extended this reasoning into a Quadruple Helix, arguing that innovation in a knowledge economy operates as a fractal ecosystem of overlapping actors rather than a pipeline, while Leydesdorff (2012) shows that the strength of these systems can be measured precisely because information circulates among helices in multiple directions rather than along one path. Within the entrepreneurial ecosystems literature, Spigel (2017) similarly argues that ecosystem attributes are relationally, not sequentially, organised, and Stam (2015) cautions that policy frameworks which treat ecosystem elements as a linear production function misrepresent how these systems actually function. Adner (2017) makes the general structural point most directly: ecosystem actors are best modelled as a multilateral network of interdependent activities, not a chain of bilateral exchanges. Taken together, this literature supports representing the Caribbean Innovation Hub Ecosystem Catalyst Framework as a networked model with multiple directions of flow, rather than as the single reinforcing cycle presented in earlier drafts of this framework.

5. Discussion

The National Innovation System framework remains a valuable lens for understanding the institutional foundations of innovation. However, its application in small economies is often constrained by structural limitations that weaken ecosystem formation and coordination. This paper argues that Caribbean Innovation Hubs can serve as practical transitional mechanisms for strengthening innovation ecosystems in such environments. By facilitating network formation, institutional bridging, and capability development, and by explicitly leveraging private sector participation and investment, innovation hubs can cultivate the institutional relationships required for more robust innovation systems to emerge over time.

The CIH model has several implications for policymakers, universities, and development partners. Governments should prioritise strengthening innovation infrastructure within universities, particularly Technology Transfer Offices and intellectual property frameworks that facilitate collaboration with firms and investors, an emphasis consistent with recent OECD (2024) guidance on university-industry collaboration. Universities should also integrate entrepreneurship and innovation education across disciplines rather than limiting these subjects to traditional STEM programmes.

Regional collaboration among Caribbean universities and innovation institutions could help avoid duplication of resources while strengthening shared capabilities. Innovation policy should also encourage private sector participation as a co-creator of innovation ecosystems, including through partnerships, venture financing mechanisms, and collaborative research initiatives. Development partners and multilateral institutions may support ecosystem development by financing early-stage innovation infrastructure, facilitating stakeholder coordination, and supporting pilot models that demonstrate the viability of innovation hubs in SIDS contexts.

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.

6. References

Adner, R. (2017). Ecosystem as structure: An actionable construct for strategy. Journal of Management, 43(1), 39–58.

Albats, E., Alexander, A. T., & Cunningham, J. A. (2022). Traditional, virtual, and digital intermediaries in university-industry collaboration: Exploring institutional logics and bounded rationality. Technological Forecasting and Social Change, 181, 121470. https://doi.org/10.1016/j.techfore.2022.121470

Allahar, H., & Sookram, R. (2019). Emergence of university-centred entrepreneurial ecosystems in the Caribbean. Industry and Higher Education, 33(6), 375–385.

Beltrán-Morales, L. F., Almendarez Hernández, M. A., Flores-Armillas, V. H., Trejo, K. S., Lagunas Vázquez, M., & Ortega Rubio, A. (2020). Technology transfer offices as promoters of technology, innovation and regional development in Mexico. International Journal of Innovation: IJI Journal, 8(1), 121–136.

Carayannis, E. G., & Campbell, D. F. J. (2009). 'Mode 3' and 'Quadruple Helix': Toward a 21st century fractal innovation ecosystem. International Journal of Technology Management, 46(3-4), 201–234.

Edquist, C., & Hommen, L. (Eds.). (2008). Small country innovation systems: Globalization, change and policy in Asia and Europe. Edward Elgar Publishing.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From National Systems and 'Mode 2' to a Triple Helix of university-industry-government relations. Research Policy, 29(2), 109–123.

Freeman, C. (1987). Technology policy and economic performance: Lessons from Japan. Pinter.

Gibb, A., & Hannon, P. (2006). Towards the entrepreneurial university. International Journal of Entrepreneurship Education, 4(1), 73–110.

Howells, J. (2006). Intermediation and the role of intermediaries in innovation. Research Policy, 35(5), 715–728.

King, G. S., Cameron, C. R., Pun, K. F., & Lewis, W. G. (2012). University-industry collaboration to engender innovation in the English-speaking Caribbean. In ISPIM Conference Proceedings (p. 1). The International Society for Professional Innovation Management.

Klerkx, L., & Leeuwis, C. (2009). Establishment and embedding of innovation brokers at different innovation system levels: Insights from the Dutch agricultural sector. Technological Forecasting and Social Change, 76(6), 849–860.

Leydesdorff, L. (2012). The Triple Helix, Quadruple Helix, …, and an N-tuple of helices: Explanatory models for analyzing the knowledge-based economy? Journal of the Knowledge Economy, 3(1), 25–35.

Lundvall, B. (2007). National innovation systems: Analytical concept and development tool. Industry and Innovation, 14(1), 95–119.

Morrar, R., & Arman, H. (2024). The transformational role of a third actor within the Triple Helix Model – the case of Palestine. *Innovation: The European Journal of Social Science Research*, *37*(2), 340–360. https://doi.org/10.1080/13511610.2020.1828045

Nelson, R. R., & Winter, S. G. (1982). An evolutionary theory of economic change. Harvard University Press.

OECD. (2024). University-industry collaboration. OECD Publishing.

Siegel, D. S., Veugelers, R., & Wright, M. (2007). Technology transfer offices and commercialization of university intellectual property: Performance and policy implications. Oxford Review of Economic Policy, 23(4), 640–660.

Soete, L., Verspagen, B., & Ter Weel, B. (2010). Systems of innovation. In B. H. Hall & N. Rosenberg (Eds.), Handbook of the economics of innovation (Vol. 2, pp. 1159–1180). Elsevier.

Spigel, B. (2017). The relational organization of entrepreneurial ecosystems. Entrepreneurship Theory and Practice, 41(1), 49–72.

Stam, E. (2015). Entrepreneurial ecosystems and regional policy: A sympathetic critique. European Planning Studies, 23(9), 1759–1769.

Vefago, Y. B., Trierweiller, A. C., & Barcellos de Paula, L. (2020). The third mission of universities: The entrepreneurial university. Brazilian Journal of Operations & Production Management, 17(4), 1–12.

Watkins, A., Papaioannou, T., Mugwagwa, J., & Kale, D. (2015). National innovation systems and the intermediary role of industry associations in building institutional capacities for innovation in developing countries: A critical review of the literature. Research Policy, 44(8), 1407–1420. https://doi.org/10.1016/j.respol.2015.05.004

Weerasinghe, R. N., Jayawardane, A. K. W., & Huang, Q. (2024). Critical inquiry on National Innovation System: Does NIS fit with developing countries? Sustainable Technology and Entrepreneurship, 3(1), 100052. https://doi.org/10.1016/j.stae.2023.100052

Wilson, S., Maharaj, C. S., & Maharaj, R. (2020). Formalising the national innovation system in a developing country. The West Indian Journal of Engineering, 42(2), 5–15.

Internationally Embedded Innovation Systems in Caribbean SIDS: Converting External Knowledge into Local Technological Capability

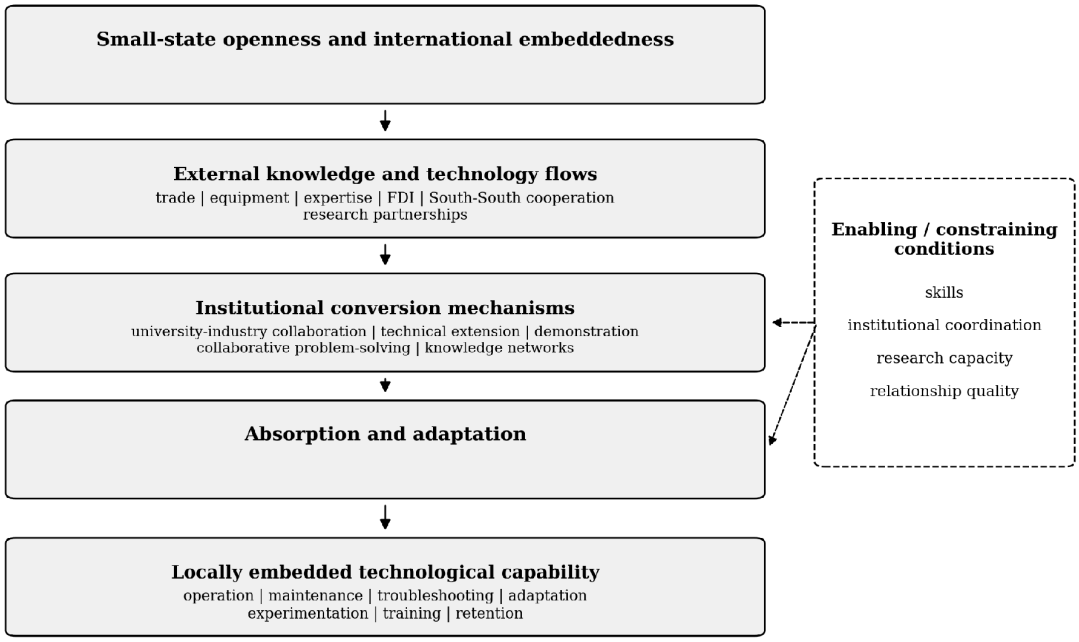
Renrick Bedeau
University of Gloucestershire, renrick.bedeau@gmail.com

1. Introduction

Caribbean small island developing states (SIDS) are structurally open economies whose small size, narrow production bases, and exposure to external shocks have long been treated as sources of vulnerability (Briguglio, 2014; Briguglio et al., 2009). This openness extends to knowledge and technology: Caribbean firms and public institutions rely heavily on imported equipment, foreign expertise, and externally financed research (ECLAC, 2011, 2012). At the same time, the region's science, technology and innovation (STI) landscape is widely described as fragmented, with numerous regional bodies but limited policy integration and weak coordination between universities, firms, and public agencies (ECLAC, 2026).

These two conditions - external reliance and domestic fragmentation - are usually discussed separately: the first as an economic-geography problem, the second as an institutional one. This paper treats them as connected. Caribbean SIDS are not simply innovation systems that happen to import more than they should; their small scale makes international knowledge and technology flows a structural feature of their innovation systems rather than an occasional supplement to them. The developmental question this raises is not whether Caribbean economies should reduce external reliance - for most SIDS this is not a realistic policy goal - but whether the institutional relationships surrounding that reliance allow externally sourced knowledge to be absorbed, adapted, and retained locally, rather than simply accessed and used. The existing literature establishes that access does not straightforwardly translate into capability. Innovation in Caribbean manufacturing firms is associated with size, export orientation, and the use of imported capital goods, while the relationship with foreign ownership itself is mixed rather than uniformly absent (Mohan et al., 2016, 2017a), as Section 2 details. Skills constraints are repeatedly identified as a binding bottleneck (Khadan, 2018; Rosenblatt et al., 2024). What remains underspecified is the institutional mechanism: how, if at all, imported knowledge and technology are converted into capability that persists locally rather than depending on continued external involvement. This paper addresses that gap through the following research question: through what institutional mechanisms do internationally embedded innovation systems in Caribbean SIDS convert externally sourced knowledge into locally embedded technological capability? It develops and critically evaluates the internationally embedded innovation systems lens - a conceptual synthesis proposed here, not an established term in the literature - as an alternative to viewing Caribbean SIDS as bounded national systems judged against a self-sufficiency benchmark they were never structurally positioned to meet. Figure 1 summarises this proposed knowledge-conversion process and the enabling and constraining conditions examined in the analysis.

Figure 1. Internationally embedded innovation system and knowledge-conversion process



Source: Author's synthesis based on Cohen and Levinthal (1990), Adeoti (2002), Denner (2012), Pereira and Steenge (2022), and Cirera and Maloney (2017).

The paper proceeds as follows. Section 2 reviews the literature on Caribbean innovation dependence, absorptive capacity, and external knowledge relationships. Section 3 outlines the integrative documentary method. Section 4 develops four propositions culminating in the internationally embedded innovation systems concept. Section 5 sets out next steps for doctoral fieldwork.

2. Literature Review

2.1 Caribbean innovation systems and international knowledge dependence

Caribbean STI institutions are characterised in the regional literature as numerous but poorly integrated. ECLAC (2026) identifies a lack of policy integration and continued reliance of national research systems on external funding as persistent features of the regional ecosystem, consistent with earlier ECLAC assessments describing a historical emphasis on importing equipment and technology over developing indigenous research capacity (ECLAC, 2011, 2012). The persistence of this characterisation across roughly a decade and a half of ECLAC reporting suggests a structural condition rather than a transitional phase. Firm-level evidence from the IDB's Caribbean innovation surveys reinforces this picture from a different angle, though the foreign-ownership findings are more mixed than a single summary figure suggests. Mohan et al. (2016) find that foreign ownership does not significantly predict a Caribbean firm's decision to invest in innovation, although it does positively predict technological innovation at a later stage of their sequential model. Mohan et al. (2017a), analysing FDI specifically, find the opposite sign on a related measure: foreign ownership reduced the probability of product or process innovation, while foreign inputs - distinct from foreign ownership - increased it, and horizontal

FDI spillovers to domestic firms were not statistically significant. These findings do not converge on a single clean relationship between foreign ownership and innovation; what they consistently support is a narrower point, developed further in Section 4, that the presence of an international ownership or supply channel does not by itself demonstrate that locally retained technological capability has resulted. This also cautions against a common policy assumption - that attracting FDI will, by itself, seed domestic innovation capacity - since the regional data do not support that inference. Human capital constraints compound the picture. Khadan (2018) and Rosenblatt et al. (2024) both identify skills deficiencies as a principal barrier facing potential innovators, with the latter noting particularly low rates of digital innovation adoption. University- industry interaction, which might otherwise compensate for firm-level skills gaps, has had limited and largely project-based success historically; King and Cameron (2013) document a specific model in Trinidad and Tobago's energy sector, built around the country's Metal Manufacturing and Engineering Research Centre, but this remains an isolated rather than systemic example. Taken together, these strands describe a regional system in which external inputs are structurally necessary, formal domestic coordinating mechanisms exist but are thin, and the skills base needed to convert either into sustained innovative activity is itself constrained.

2.2 Absorptive capacity and technological capability

The theoretical vocabulary for interpreting this pattern comes from absorptive capacity theory, which describes an organisation's capacity to recognise the value of external knowledge, assimilate it, and apply it to commercial or productive ends (Cohen & Levinthal, 1990). Absorptive capacity supplies a plausible conceptual bridge between access to external knowledge and its application, a bridge the mixed Caribbean firm-level findings above are consistent with, though those findings do not by themselves establish which firms possess or lack absorptive capacity. A related distinction concerns technological capability: the difference between using an imported technology and possessing the locally retained capacity to operate, troubleshoot, maintain, adapt, and eventually redevelop it (Adeoti, 2002). Cirera and Maloney (2017) formalise a related idea as an "innovation paradox," in which developing-country firms under-invest in the capabilities needed to climb a technological "capabilities escalator" even where formal incentives to innovate exist - a lens applied further in Section 4.

2.3 External knowledge relationships and the conversion problem

A third strand addresses how external relationships themselves shape - or fail to shape - this conversion. Pereira and Steenge (2022) argue that connectivity to metropolitan and international partners is a meaningful resilience factor for small island states, but note that the same connectivity implies dependency, since the state's fortunes become tied to shocks originating elsewhere. Denner (2012) similarly frames knowledge networks as a deliberate institutional tool through which Caribbean SIDS might convert external linkages into developmental capacity, though the framing is more prescriptive than empirically demonstrated within the region. South-South cooperation (SSC) offers a further, more mixed body of evidence, and one particularly relevant to the mechanism question this paper poses. UNCTAD (2012) cautions that access to knowledge through SSC arrangements can remain "access to information" where recipient actors lack the capacity to build upon it - echoing the absorptive capacity problem above and reinforcing that SSC is not, by virtue of shared developing-country status, automatically more conducive to capability transfer than North-South arrangements. Graber and Rault-Chodankar's (2026) study of an Indo-Cuban biopharmaceutical collaboration documents a case in which SSC generated real capability and learning over a sustained period, but also

encountered structural tensions and eventual institutional breakdown attributed to divergent value regimes between partners - instructive precisely because it does not resolve cleanly in either direction. Lin and Cui (2024) find that Chinese agricultural technology demonstration centres in Africa improved food-security outcomes through structured, hands-on demonstration, using a rigorous triple-difference-in-differences design - one of the few SSC mechanisms in the corpus with a defensible empirical evaluation attached. However, the evidence is African, not Caribbean, and concerns a different commodity and institutional context; its transferability to small-island settings should be treated as inferred rather than established, and this paper does not claim otherwise. Taken together, this literature identifies that conversion from external knowledge to local capability is uneven, but stops short of specifying the institutional mechanisms through which conversion is supposed to occur in a Caribbean SIDS setting. That is the gap this paper addresses.

3. Methodology

This paper is framed as a focused integrative literature review and theory-building documentary analysis, rather than a systematic review, since no formal systematic-review protocol was applied. A purposively constructed corpus of 25 sources was assembled across five bodies of literature: Caribbean innovation systems and STI institutions; Caribbean firm-level innovation and capability; small-state vulnerability and resilience; absorptive capacity, technological capability, and innovation-systems theory; and international and South-South technology and knowledge cooperation. Sources within each body were located through targeted searches and citation tracing from key texts, with selection prioritising Caribbean empirical studies, authoritative regional policy evidence (principally ECLAC and IDB publications), foundational absorptive-capacity and technological-capability theory, and comparator South-South technology-transfer studies capable of speaking to the mechanism question where Caribbean-specific evidence is absent. Sources were classified by the type of evidentiary support they offer: direct empirical findings (results from primary Caribbean data, such as the IDB firm surveys); cross-source synthesis (claims built by combining separate sources, such as the internationally embedded innovation systems lens itself); theoretical inference (claims drawn from theory rather than regional data); and relationships that remain untested within the corpus (such as the applicability of African SSC demonstration-centre evidence to Caribbean agriculture). This classification allows the analysis in Section 4 to distinguish, proposition by proposition, between claims resting on Caribbean data and claims extending comparator or theoretical evidence, a distinction preserved throughout rather than collapsed for narrative convenience. Three limitations should be acknowledged. First, the corpus's strongest quantitative evidence - the IDB Caribbean firm-innovation surveys underpinning Dohnert et al. (2017), Mohan et al. (2016, 2017a, 2017b), and Khadan (2018) - derives substantially from data collected around 2014. Second, this evidence is manufacturing-heavy despite services' dominance of most Caribbean economies. Third, evidence specific to smaller OECS states is thinner than for larger territories such as Trinidad and Tobago, and no longitudinal evidence in the corpus traces capability retention over time within a single Caribbean case. These limitations shape the conditional, proposition-based structure of the analysis that follows.

4. Analysis of Results

Proposition 1: Access is not capability.

The clearest pattern in the Caribbean evidence base is that external connectivity and imported technology create technological opportunity without themselves demonstrating that locally embedded capability has resulted. The foreign-ownership evidence illustrates this precisely because it does not resolve into a single tidy finding. Mohan et al. (2016) find that foreign ownership does not significantly predict a firm's decision to invest in innovation, though it positively predicts technological innovation once that investment stage is reached. Mohan et al. (2017a), examining FDI specifically, find that foreign ownership reduced the probability of product or process innovation, that foreign inputs increased it, and that horizontal spillovers to domestic firms were not statistically significant. These results are mixed rather than uniform, and are consistent with - without directly establishing - an absorptive-capacity explanation, in which the presence of an international channel does not by itself guarantee the organisational capacity to recognise, assimilate, and apply what that channel makes available (Cohen & Levinthal, 1990); the surveys do not measure absorptive capacity itself. What the findings do support, more narrowly, is that international ownership or supply access is not a reliable proxy for locally retained technological capability, whatever the underlying mechanism. Training data reinforce this caution. In-firm training's estimated effect on innovation probability is negligible or statistically insignificant in several Caribbean models (Khadan, 2018; Mohan et al., 2017b), indicating that even direct, purpose-built skills interventions do not reliably translate into innovation outcomes. None of these forms of access is sufficient on its own to demonstrate locally embedded capability, and treating any one of them as a proxy for capability risks overstating how much conversion has actually occurred.

Proposition 2: Fragmented institutional linkages constrain conversion.

Where Proposition 1 addresses firm-level access, Proposition 2 addresses the surrounding institutional architecture, drawing on evidence specific to Caribbean STI systems rather than inferring institutional thinness from firm-level absorptive-capacity theory. ECLAC (2026) characterises the regional STI ecosystem as lacking policy integration, with national research systems remaining heavily dependent on external funding rather than embedded in dense domestic linkages between universities, public agencies, and productive sectors. This regional-system evidence, rather than theoretical extrapolation from the firm level, is the basis for treating institutional thinness as a documented feature of the Caribbean case. University-industry interaction, one of the few mechanisms with documented Caribbean evidence, has produced identifiable models - such as the collaboration structure documented in Trinidad and Tobago's energy sector, built around a dedicated research and engineering centre (King & Cameron, 2013) - but these appear as isolated instances rather than a systemic feature, and the broader literature describes such relationships as often weak or project-based. Skills constraints (Khadan, 2018; Rosenblatt et al., 2024) compound this fragmentation: firms and public agencies that might wish to absorb external knowledge may lack the internal technical capacity to do so, and the intermediary institutions - brokers, extension services, sustained university partnerships - that a less fragmented system might supply to compensate are themselves reported as thin regionally. The result, on this Caribbean-specific evidence, is that the institutional linkages through which absorption might be actively cultivated and diffused beyond a single project are structurally underdeveloped, which helps explain why isolated successes such as the Trinidad and Tobago model have not generalised.

Proposition 3: Conversion depends on interaction and adaptation, not passive transfer.

If access and fragmented linkages jointly explain why conversion is incomplete, the literature also offers partial evidence on what conversion looks like when it does occur. The recurring theme across the strongest available cases is that successful mechanisms are interactive, relational, and context-dependent rather than a one-directional handover of equipment or instructions. Cesarino's (2013) dissertation-based study of Brazil-Africa South-South cooperation in agriculture offers the corpus's most direct evidence on this point: capacity-building and technology adaptation are documented as processes of "context-making," in which recipient and provider actors jointly co-produce a version of the technology fitted to local conditions, rather than the recipient simply receiving a fixed package. Cesarino also documents organisational fragility and open questions about project robustness and continuity in these arrangements, with outcomes uneven across cases. This adds a relational dimension the mechanism question needs: conversion appears to depend not only on which mechanism (extension, demonstration, collaboration) is used, but on how robustly the relationship sustaining it is maintained over time. Rogers's (2016) functional analysis of the Barbados solar water heater industry documents a comparable pattern within the Caribbean itself: early development succeeded through policy-driven incentives alongside functioning technical-assistance and extension relationships. However, the same case later entered market stagnation as stakeholder-network functions weakened - a caution, consistent with Cesarino's fragility finding, that conversion mechanisms require ongoing institutional maintenance rather than a one-time intervention. Lin and Cui's (2024) evidence on Chinese demonstration centres in Africa is retained here only as further, qualified, comparator evidence for structured demonstration as a mechanism, given the African-not-Caribbean caveat discussed in Section 2.3. Graber and Rault-Chodankar's (2026) Indo-Cuban case adds a sobering qualification of its own: even a genuinely interactive SSC relationship that produces real, sustained learning is not self-sustaining once value-regime tensions cause the underlying institutional relationship to dissolve. Read together, these cases suggest that candidate conversion mechanisms available to the region - technical extension, demonstration, collaborative problem-solving, knowledge networks (Denner, 2012) - are plausible but precarious. They can support learning, adaptation, and capability formation under the right institutional conditions, but durable local retention remains insufficiently demonstrated across the corpus; none of the cases supports treating such mechanisms as self-sustaining once established, and each requires continued relational maintenance to avoid the stagnation, fragility, or dissolution observed in Barbados, in the Brazil-Africa cases, and in the Indo-Cuban case respectively.

Proposition 4: International embeddedness is both an opportunity and a vulnerability.

The preceding propositions point toward a reframing rather than a resolution. Pereira and Steenge (2022) show that connectivity to external partners is a meaningful resilience factor for small island states, while simultaneously tying those states to shocks originating in partner economies. This dual character extends beyond economic resilience to knowledge relationships specifically: the same international linkages that expose Caribbean SIDS to imported equipment, foreign expertise, and SSC partnerships also expose them, as the Indo-Cuban case shows, to institutional tensions that no single participating actor fully controls. Given the region's small scale, structural openness is a persistent structural condition that cannot realistically be eliminated; the policy-relevant question is therefore not how to achieve technological self-sufficiency, but how domestic institutions can retain agency, learning, and problem-solving capacity within international relationships that will, by structural necessity, continue. This is the

basis for proposing an internationally embedded innovation systems lens: a way of viewing Caribbean SIDS innovation systems in which international knowledge and technology flows are treated not as an external supplement to an otherwise bounded domestic system, but as a structural component of the system itself. This framing synthesises connectivity theory's resilience- dependency duality (Pereira & Steenge, 2022), Cirera and Maloney's (2017) capabilities-escalator account of international technology diffusion, and Denner's (2012) knowledge-networks framework; it is not a term used elsewhere in the reviewed literature and is advanced here as this paper's conceptual contribution. Under this framing, "external reliance" ceases to be read as system failure and becomes instead the starting condition against which institutional capacity for absorption, adaptation, and retention must be assessed. This reframing has an implication for how the four propositions above should be read together, rather than separately. Proposition 1 shows that access does not equal capability; Proposition 2 identifies, from Caribbean institutional evidence specifically, part of why - fragmented domestic linkages constrain absorption; Proposition 3 identifies candidate mechanisms through which absorption can nonetheless occur, while showing that each is precarious rather than self-sustaining; and Proposition 4 argues that the openness underlying all three is not itself the problem to be solved. The four propositions therefore point toward a single underlying claim: capability formation in Caribbean SIDS depends not on openness alone, but on the institutional arrangements built within it. This is a modest but analytically useful reorientation. It shifts the evaluative question away from how dependent a Caribbean innovation system is, and toward how well-designed its international relationships are for retaining learning, agency, and problem-solving capacity locally.

5. Next Steps

This proceedings article develops the internationally embedded innovation systems concept theoretically, from a documentary corpus rather than original fieldwork; no interviews or primary empirical data have been collected for this stage of the research. The doctoral research programme from which this paper is drawn will test the proposition empirically through purposively selected sectoral case studies within Caribbean SIDS, combining semi-structured interviews with firm, university, and public-agency actors, documentary evidence on specific technology partnerships, and, where feasible, longitudinal or process-tracing methods that follow a partnership's development over time rather than capturing a single cross-sectional snapshot. Fieldwork will need to move beyond the presence of a conversion mechanism - a training programme, a demonstration project, a university-industry agreement - to observable indicators of whether locally embedded capability actually results. Candidate indicators, informed by the technological capability literature (Adeoti, 2002), include: independent operation of the technology without ongoing external supervision; local capacity for maintenance and troubleshooting; adaptation of imported technology to local conditions; local experimentation beyond the technology's original design parameters; local technical problem-solving in response to failures or changing requirements; the capacity of local actors to train others; and, most stringently, whether locally retained knowledge and functioning persist after external partners withdraw. None of these indicators has been empirically observed within the present study; they are proposed here as the analytical targets for the empirical phase of the research.

6. References

Adeoti, J. O. (2002). Building technological capability in the less developed countries: The role of a national system of innovation. *Science and Public Policy, 29*(2), 95-104.

Briguglio, L. (2014). A vulnerability and resilience framework for small states. In D. Bynoe-Lewis (Ed.), *Building the resilience of small states: A revised framework* (pp. 1-102). Commonwealth Secretariat.

Briguglio, L., Cordina, G., Farrugia, N., & Vella, S. (2009). Economic vulnerability and resilience: Concepts and measurements. *Oxford Development Studies, 37*(3), 229-247.

Cesarino, L. (2013). *South-South cooperation across the Atlantic: Emerging interfaces in international development and technology transfer in agriculture* [Doctoral dissertation, University of California, Berkeley].

Cirera, X., & Maloney, W. F. (2017). *The innovation paradox: Developing-country capabilities and the unrealized promise of technological catch-up*. World Bank.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly, 35*(1), 128-152.

Denner, K. (2012). *Employing knowledge networks as tools for the development of Caribbean small island developing states*. ECLAC.

Dohnert, S., Crespi, G., & Maffioli, A. (Eds.). (2017). *Exploring firm-level innovation and productivity in developing countries: The perspective of Caribbean small states*. Inter-American Development Bank. https://doi.org/10.18235/0000616

ECLAC. (2011). *Study on the vulnerability and resilience of Caribbean SIDS*. Economic Commission for Latin America and the Caribbean.

ECLAC. (2012). *Development paths in the Caribbean*. Economic Commission for Latin America and the Caribbean.

ECLAC. (2026). *Repositioning science, technology and innovation for sustainable development in Caribbean SIDS* (LC/CAR/2026/1). Economic Commission for Latin America and the Caribbean.

Graber, N., & Rault-Chodankar, Y.-M. (2026). Between technology transfer and South-South collaboration: An Indo-Cuban experiment in biopharmaceutical innovation. *BioSocieties, 21*, 158-183.

Khadan, J. (2018). *Estimating the effects of human capital constraints on innovation in the Caribbean*. Inter-American Development Bank.

King, G. S., & Cameron, C. R. (2013). An enhanced model for university-industry collaboration for innovation in Trinidad and Tobago. *West Indian Journal of Engineering, 36*(1), 86-94.

Lin, S., & Cui, J. (2024). South-South cooperation and food security: Evidence from Chinese agricultural technology demonstration centre in Africa. *China Economic Quarterly International, 4*(1), 1-12.

Mohan, P., Watson, P., & Strobl, E. (2016). Innovative activity in the Caribbean: Drivers, benefits and obstacles. In M. Grazzi & C. Pietrobelli (Eds.), *Firm innovation and productivity in Latin America and the Caribbean* (pp. 73-101). Palgrave Macmillan.

Mohan, P., Strobl, E., & Watson, P. (2017a). Foreign direct investment and innovation and productivity in the Caribbean. In S. Dohnert, G. Crespi, & A. Maffioli (Eds.), *Exploring firm-level innovation and productivity in developing countries: The perspective of Caribbean small states* (pp. 63-84). Inter-American Development Bank.

Mohan, P., Strobl, E., & Watson, P. (2017b). *In-firm training, innovation and productivity: The case of Caribbean SIDS* (IDB Working Paper Series No. IDB-WP-778). Inter-American Development Bank.

Pereira, E. E., & Steenge, A. E. (2022). Vulnerability and resilience in the Caribbean island states: The role of connectivity. *Networks and Spatial Economics, 22*, 515-540.

Rogers, T. (2016). Development of innovation systems for small island states: A functional analysis of the Barbados solar water heater industry. *Energy for Sustainable Development, 31*, 143-151.

Rosenblatt, D., Beuermann, D., Dohnert, S., Clayton, K., Saboin, J. L., Mazzocca, A., Ortiz de Mendívil, C., Gauto, V., Hussain, L., & Castilleja Vargas, L. (2024). *Caribbean Economics Quarterly: Volume 13, Issue 3: Innovation for faster economic growth in the Caribbean: Are we there yet?* Inter-American Development Bank. https://doi.org/10.18235/0013347

UNCTAD. (2012). *Technology and innovation report 2012: Innovation, technology and South-South collaboration*. United Nations.

Economic Diversification and Employment Patterns in Emerging Oil Economies: Insights from Guyana

Shenika Marks-James
ARKA Jain University, shenikamarks.james@gmail.com

1. Introduction

Guyana's economic trajectory following the 2015 offshore discoveries within the Stabroek Block represents a classic development economics phenomenon (McDonald & Üngör, 2021). Between 2020 and 2024, real GDP expanded at an unprecedented average rate of 47% per annum (IMF, 2025). While this capital windfall offers a rare opportunity to alleviate infrastructure deficits, it simultaneously exposes a small economy to severe Dutch Disease distortions, localised inflation, and structural hollowing out (Balza et al., 2020; World Bank, 2025).

The primary vector of transmission is the Dutch Disease framework, where a booming primary resource export sector triggers real exchange rate appreciation and localised wage premiums (Corden & Neary, 1982). This pulls capital and labour away from traditional tradeable sectors like agriculture toward the resource enclave and non-tradeable sectors, primarily construction and public services, which are directly fueled by state capital expenditure (Hvidt, 2020; Ministry of Finance Guyana, 2025; Ross, 2017). This paper evaluates these dynamics to provide critical insights for policy formulation.

Guyana's capital-intensive petroleum extraction directly absorbs less than 5% of the workforce (World Bank, 2026). The remaining labour force is subject to localised inflation, wage distortions, and skills mismatches (Jouili & Khemissi, 2019). Benchmarking Guyana against Gabon (an established capital-scarce petrostate), Qatar (a capital-surplus petro-enclave), and Costa Rica (a diversified regional control) provides critical insights. The paper is structured as follows: Section 2 reviews the literature; Section 3 outlines the methodology and panel benchmarks; Section 4 analyzes results; and Section 5 details policy recommendations.

2. Literature Review

This study integrates three economic theories. First, Dutch Disease theory (Corden & Neary, 1982) explains how resource booms trigger spending and resource movement effects, hollowing out traditional tradeable sectors. Second, the Hartwick Rule (Hartwick, 1977) requires resource rents to be fully reinvested into reproducible capital, notably infrastructure and human capital (McDonald & Üngör, 2021). Third, Institutional Moderation Theory (Musikavanhu et al., 2026; Senadjki et al., 2025) asserts that commodity shock transmission to labour markets is actively moderated by domestic labour market institutions (LMIs), such as collective bargaining and social safety nets.

Nigeria serves as a cautionary model of heavy oil reliance and weak industrial policy, resulting in agricultural hollowing out, exchange rate crises, and high youth unemployment (Alley, 2018; Flores, 2023; Obakhume, 2026). Conversely, Saudi Arabia illustrates a model of state-led

dominance attempting to shift toward digital and service growth to reduce public sector reliance and foster private sector localisation (Alkhathlan et al., 2020; Neffati & Jbir, 2024).

Qatar represents a capital-surplus enclave with a small native population, where imported expatriate labour creates a native 'technical glass ceiling' (Kaya et al., 2019; Tok et al., 2020). Conversely, Gabon is a capital-scarce petrostate where rigid labour institutions contribute to persistent youth unemployment (Musikavanhu et al., 2026). Finally, Costa Rica serves as a regional control. Lacking oil enclaves, Costa Rica successfully diversified into high-value manufacturing and services, providing a baseline to isolate oil-induced Dutch Disease distortions from general growth trends (Ferreira, 2009; Corden & Neary, 1982). Comparing Guyana against Costa Rica's non-oil trajectory isolates specific Dutch Disease symptoms and validates whether labour market adjustments are direct consequences of a highly concentrated extractive sector.

3. Methodology

To evaluate structural shifts in Guyana's emerging petroleum economy, this study employs a mixed-method policy analysis framework integrated with descriptive labour market decomposition. Rather than estimating formal causal allocation equations on limited local time-series data, this study interprets labour reallocation through a series of key descriptive indicators, benchmarking them against two established global panel data models to draw robust comparative inferences.

The quantitative component utilises datasets from the Guyana Bureau of Statistics (2024), the IMF (2025), and the Ministry of Finance (2025), decomposed across four key dimensions: demographic segmentation, sectoral allocation, institutional distribution, and geographic shifts. Qualitative comparative policy analysis of Saudi Arabia, Nigeria, Gabon, Qatar, and Costa Rica contextualises Guyana's structural trajectory.

Observed domestic patterns are benchmarked against two econometric panels. The first is an FGLS model evaluating the impact of economic and structural variables on economic diversification across 14 resource-rich countries (Jolo et al., 2022). The second is a CS-ARDL model examining how the Labour Market Institutional Index (LMII) moderates the impact of resource price shocks on unemployment across 9 oil-exporting economies (Musikavanhu et al., 2026). Costa Rica serves as the vital non-oil baseline control to isolate resource-specific Dutch Disease distortions from general regional growth trends.

4. Analysis of Results

4.1 Comparative Labour Demographics and the Macro-Micro Paradox

Guyana's macroeconomic landscape features a classic dual-economy structure. While real GDP expanded by an extraordinary 43.6% in 2024, the non-oil sector grew at a lower rate of 13.1%, heavily concentrated in public logistics and infrastructure dependent on central government capital spending (IMF, 2025; Ministry of Finance Guyana, 2025). The national unemployment rate dropped to a historic low of 6.8% in Q4 2024 (Guyana Bureau of Statistics, 2024). However, as shown in Table 1, a granular review of the labour force microdata reveals deep structural disparities.

Table 1. Macroeconomic and Labour Market Indicators in Guyana (2022–2026)

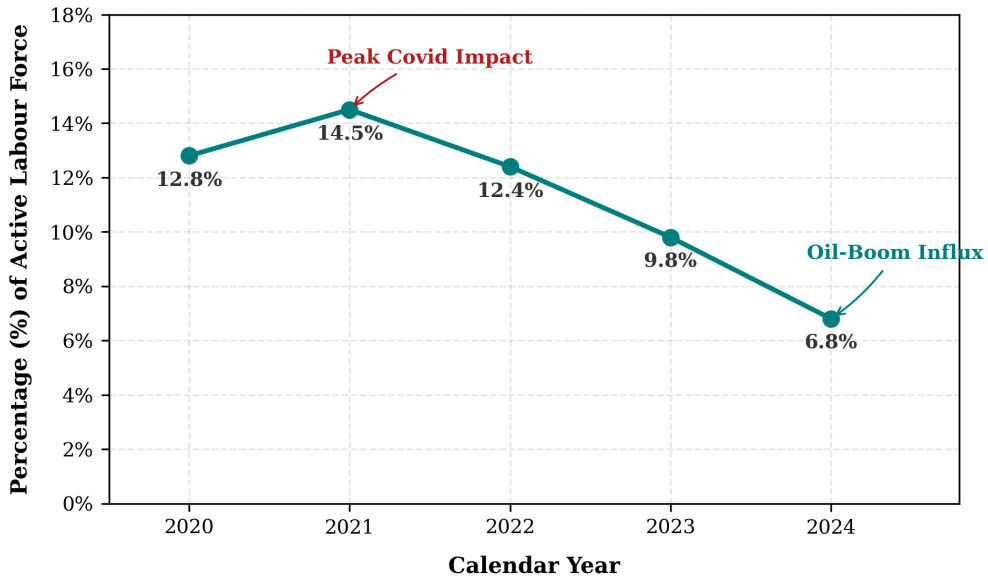
Macroeconomic & Labour Indicator	2022	2023	2024	2025 (Est.)	2026 (Proj.)
Real GDP Growth (%)	62.3%	33.0%	43.6%	21.4%	15.8%
Non-Oil Real GDP Growth (%)	11.5%	9.1%	13.1%	8.3%	6.5%
Consumer Price Inflation (%)	7.2%	2.0%	2.9%	4.2%	5.5%
National Unemployment Rate (%)	12.4%	9.8%	6.8%	7.1%	7.4%
Youth Unemployment Rate (%)	28.5%	19.4%	12.1%	13.5%	14.2%
Private Sector Share of Jobs (%)	54.1%	55.8%	57.6%	58.0%	58.2%

Source: Estimates and projections compiled from IMF (2025) and Ministry of Finance (2025).

In Q4 2024, female unemployment (9.3%) remains nearly double male unemployment (5.1%). This gender gap expands significantly within the youth cohort (ages 15–24), where female youth unemployment reaches 17.2%, compared to 8.4% for young males (Guyana Bureau of Statistics, 2024). This disparity highlights that the primary employment pathways generated by the resource boom—such as construction and civil engineering—are structurally aligned with historically male-dominated industries, while job growth in sectors with higher female participation lags behind (McDonald & Üngör, 2021).

This demographic segmentation and the resulting macro-micro paradox are illustrated by the unemployment contraction curve (Figure 1). While the drop from 14.5% in late 2021 to 6.8% in late 2024 represents a remarkable headline achievement, this positive trajectory remains structurally fragile. Because the employment expansion is primarily driven by indirect non-tradeable sectors funded by NRF fiscal transfers, rather than organic non-resource tradeable expansion, the labour market remains highly vulnerable to commodity price shocks.

Figure 1. Decline in Guyana's National Unemployment Rate, 2020–2024



Source: Plotted using tracking indicators extracted from the Guyana Bureau of Statistics Annual and Quarterly Labour Force Survey Bulletins (2020–2024).

4.2 Demographic Segmentations and Labour Market Disparities

To understand how demographic and gender disparities are consolidated under Dutch Disease, we examine hollowing-out effects across traditional sectors. The concentration of public capital infrastructure and shore-base operations along the Demerara River corridor has triggered a wave of internal rural-to-urban migration, drawing agricultural workers out of the rice and sugar fields of Regions 5 and 6 (Guyana Bureau of Statistics, 2024; IMF, 2025). This drains agricultural hubs of essential seasonal labour, raising domestic food production costs and import reliance.

Simultaneously, an internal brain drain has emerged, as multinational prime contractors offer substantial wage premiums that local public institutions, SMEs, and traditional domestic tradeable firms cannot match. This factor-price distortion pulls skilled professionals out of critical public services and into corporate roles within the energy supply chain, reducing the international competitiveness of traditional non-oil exports and reinforcing Dutch Disease pressures.

4.3 Factor-Market Distortions: Expatriate Labour and the "Technical Glass Ceiling"

Because Guyana's historical technical baseline was geared toward primary commodities (sugar, rice, bauxite), the rapid offshore oil expansion created an immediate, acute deficit in advanced technical skills (McDonald & Üngör, 2021). To bridge this gap, multinational tier-one contractors imported thousands of highly skilled expatriate technical experts from the Caribbean, North America, and Europe (Balza et al., 2020). This parallel influx has generated dual crowding-out effects on the native population.

First, high-earning expatriates drive localised inflation in urban real estate along the Demerara River corridor, pricing native Guyanese out of primary urban zones. Second, a 'technical glass ceiling' has emerged: while native workers are rapidly absorbed into lower-multiplier construction and basic service roles, the tech-heavy, managerial core of the energy sector remains dominated by foreign nationals (Guyana Bureau of Statistics, 2024). This structural dynamic is highly visible in Qatar, which relies on a massive, imported labour force, separating a highly paid expatriate class from a native population concentrated in public administration (Kaya et al., 2019; Tok et al., 2020).

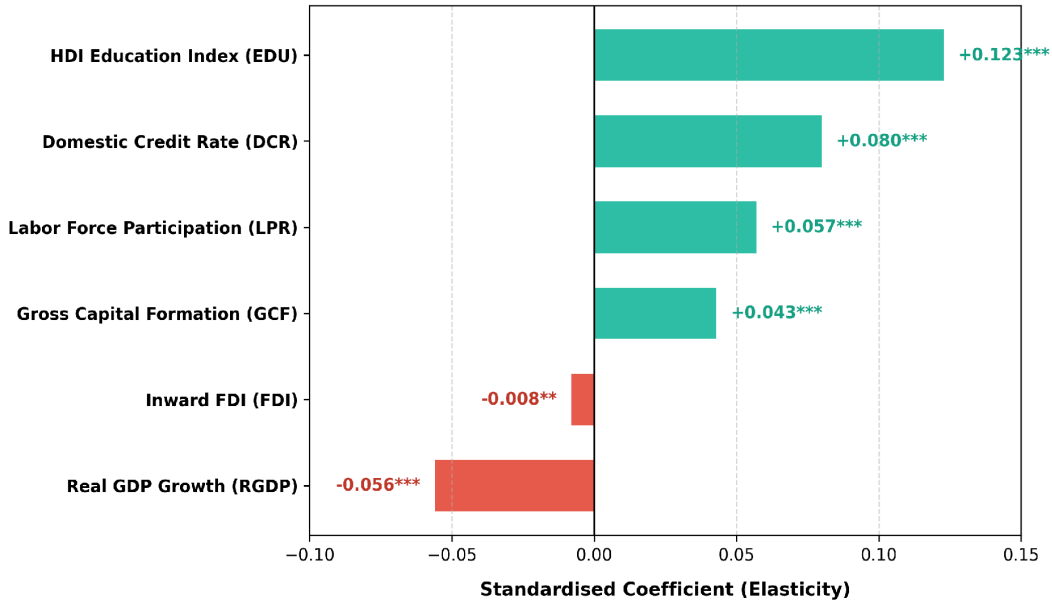
4.4 Econometric Validation and Panel Benchmarking

Applying parameters from the FGLS panel (Jolo et al., 2022) and CS-ARDL panel (Musikavanhu et al., 2026) allows for formal statistical inferences. The FGLS panel demonstrates that long-run economic diversification is negatively associated with resource-based real GDP growth ($\beta_RGDP = -0.056$, $p < 0.01$) and inward foreign direct investment ($\beta_FDI = -0.008$, $p < 0.05$). Large extractive multinational capital inflows—such as the importation of the One Guyana FPSO valued at US$2,534.1 million—reinforce resource dependency, crowding out domestic manufacturing and agriculture through real exchange rate appreciation and hollowing out adjacent tradeable sectors.

Conversely, human capital development ($\beta_EDU = 0.123$, $p < 0.01$) and labour force participation ($\beta_LPR = 0.057$, $p < 0.01$) yield the highest positive marginal returns to diversification. This explains why Costa Rica's baseline economic resilience is strongly correlated with its historical investments in human capital and balanced labour participation (Ferreira, 2009). For Guyana to escape the negative coefficient drag of resource-based growth, it

must systematically translate physical oil revenues into digital and educational assets, as illustrated in the standardised FGLS coefficient mapping.

Figure 2. Standardised FGLS Econometric Coefficients of Diversification Determinants used as an Empirical Benchmark for Guyana's Pathway



Source: Adapted from cross-country panel parameters estimated by Jolo et al. (2022).

Furthermore, the CS-ARDL panel estimation confirms that the Labour Market Institutional Index (LMII) is a critical moderator of economic shocks. The model demonstrates that the presence of strong LMIs directly reduces structural unemployment ($\beta_LMII = -0.272$, $p < 0.05$). More importantly, the interaction term between oil prices and the LMII is highly negative and significant ($\beta_OP*LMII = -0.386$, $p < 0.05$), proving that countries with high-quality, flexible labour institutions are significantly more resilient to commodity price cycles, cushioning the negative consequences of oil price shocks (Musikavanhu et al., 2026).

4.5 Sovereign Wealth Fund Governance and Fiscal Pacing

The management of Guyana's petroleum revenues is legally governed by the Natural Resource Fund (NRF) Act. While the NRF was structured to insulate the domestic economy from revenue volatility via a clear rule-based withdrawal system, recent legislative amendments have significantly increased the front-loaded ceiling for budgetary transfers (IMF, 2025; World Bank, 2026). This institutional shift permits the immediate absorption of large oil windfalls directly into the national consolidated budget to finance massive capital infrastructure programmes (Ministry of Finance Guyana, 2025).

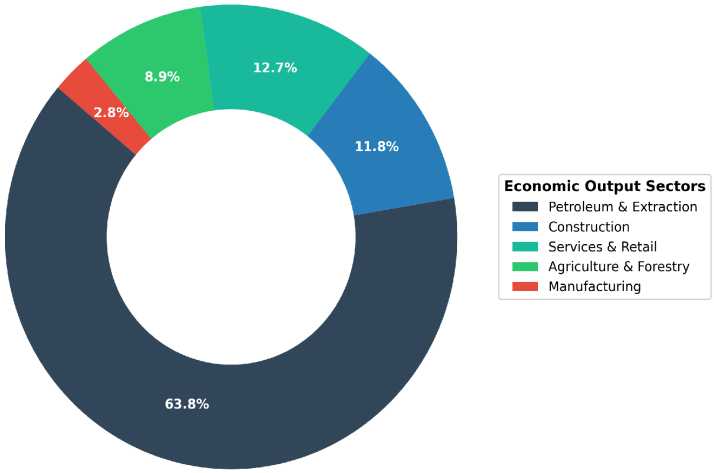
However, under the Hartwick Rule, resource depletion must be offset by the equivalent accumulation of other productive reproducible assets (Hartwick, 1977). Guyana's rapid fiscal front-loading has overwhelmed the domestic carrying capacity of its tight labour and material markets. Because the domestic supply of materials and qualified personnel is inelastic in the short run, the injection of massive fiscal liquidity has driven up consumer price inflation

(projected to reach 5.5% by 2026) and forced an unsustainable reliance on imported inputs and expatriate contractors, hollowing out the domestic multiplier effect (Musikavanhu et al., 2026).

4.6 Sectoral Concentration and the Output-Labour Decoupling

To diagnose the true state of economic diversification, the absolute structural distribution of the domestic output basket must be evaluated. The nominal distribution of sectors illustrates a massive asymmetry between the expanding extractive perimeter and the traditional, labour-absorptive non-oil industries. Figure 3 visually diagnoses Guyana's severe dual-economy vulnerability using consolidated data from the IMF (2025), the Guyana Bureau of Statistics (2024), and the Ministry of Finance Guyana (2025).

Figure 3. Structural Concentration of Guyana's Nominal GDP Shares (2025 Snapshot)



Source: Generated using statistical indicators retrieved from the International Monetary Fund (2025) and the Guyana Bureau of Statistics National Accounts Database (2024).

Nearly two-thirds (63.8%) of Guyana's nominal output is tied to a single resource extraction sector (World Bank, 2025). This proves a profound decoupling between economic output and employment: the oil sector generates the vast majority of GDP but absorbs less than 5% of formal domestic employees. This leaves the majority of the population dependent on shrinking traditional sectors or state-funded construction, exposing the country to intense Dutch Disease pressures.

4.7 The Regional Non-Oil Baseline: Isolating Dutch Disease Distortions

To isolate precise macroeconomic distortions driven by Guyana's offshore petroleum windfall, this study contrasts its trajectory with Costa Rica, the regional non-oil baseline control. Lacking extractive enclaves, Costa Rica achieved a balanced growth model where manufacturing and services expansion is closely linked to domestic human capital and high female labour force participation (Ferreira, 2009). This provides a stark contrast to Guyana’s emerging dual-economy structure, where rapid spending of the resource windfall has triggered severe localised inflation and real exchange rate appreciation, hollowing out traditional tradeable sectors like agriculture, forestry, and manufacturing (Corden & Neary, 1982; Ross, 2017).

Guyana's historic drop in unemployment to 6.8% is structurally unstable compared to Costa Rica's organic labour absorption (Guyana Bureau of Statistics, 2024). In Costa Rica, labour force participation is gender-balanced and driven by high-multiplier, knowledge-intensive sectors. In contrast, Guyana's labour market features a profound gender gap (68.2% male participation versus 44.8% female participation) and elevated female youth unemployment (17.2%), because the resource boom's indirect employment channels are concentrated in male-dominated construction and logistics (Guyana Bureau of Statistics, 2024). Costa Rica serves as a direct policy contrast, proving that long-term structural resilience requires transitioning away from transient construction cycles toward diverse, knowledge-based tradeable services.

This baseline contrast is further validated by the econometric panel benchmarking. The FGLS model demonstrates that long-run economic diversification is negatively associated with resource-based GDP growth ($\beta_RGDP = -0.056$, $p < 0.01$) and inward foreign direct investment ($\beta_FDI = -0.008$, $p < 0.05$), illustrating the structural lock-in effect of extractive enclaves (Jolo et al., 2022). Costa Rica has avoided this resource drag by systematically investing in human capital development ($\beta_EDU = 0.123$, $p < 0.01$) and active labour force participation ($\beta_LPR = 0.057$, $p < 0.01$). Conversely, Guyana's accelerated fiscal withdrawals from the Natural Resource Fund have front-loaded liquidity directly into the domestic consolidated budget, outpacing domestic carrying capacity and inducing an internal brain drain (IMF, 2025; Ministry of Finance Guyana, 2025).

Table 2. Comparative Framework of Structural Interventions and Cross-Country Policy Lessons

Country & Model	**Structural Policy Strategy**	**Labour Market Outcomes**	**Strategic Lesson for Guyana**
Nigeria (Capital-Scarce established petrostate)	Heavy oil reliance; weak industrial policy implementation (Flores, 2023).	Severe hollowing out of agriculture; persistently high youth and graduate unemployment.	Avoid rent-seeking institutional frameworks; enforce early-stage transparency (Obakhume, 2026).
Saudi Arabia (Capital-Surplus established petrostate)	Historical state dominance; recent shift toward digital and service growth (Neffati & Jbir, 2024).	High public sector reliance; rapid push for private sector localisation through digitalisation.	Diversify public wealth directly into domestic innovation infrastructure (Alkhathlan et al., 2020).
Qatar (Established Capital-Surplus Petro-Enclave)	Heavy Gross Capital Formation (GCF) in infrastructure; reliance on imported expatriate labour.	Creation of a "technical glass ceiling" for native workers; localised housing hyperinflation.	Set up robust structural joint ventures, specialised technical apprenticeships, and international certifications to systematically replace the expatriate workforce (Tok et al., 2020).
Gabon (Established Capital-Scarce Petrostate)	Oil-dependent economy; rigid labour market institutions and strict employment protection.	High structural unemployment; severe youth labour market stagnation.	Prioritise labour market institutional reforms, flexible labour policies, and targeted active labour market programmes (Musikavanhu et al., 2026).

Costa Rica (Non-Oil Regional Baseline Control)	Successfully diversified economy into high-value manufacturing, tourism, and services.	Balanced gender participation; high-value non-oil tradeable growth; strong macroeconomic resilience.	Invest systematically in human capital, technical and vocational education (TVET), and balanced labour force participation (Ferreira, 2009).
Guyana (Emerging Petrostate; current)	Rapid infrastructure expansion via Sovereign Wealth Fund (NRF) transfers.	Labour tightening in urban areas; skill shortages in traditional sectors; internal brain drain.	Implement targeted technical/vocational training matching non-oil priorities; align NRF withdrawals with domestic carrying capacity (IMF, 2025).

Source: Synthesised from Alkhathlan et al. (2020), Flores (2023), IMF (2025), Neffati & Jbir (2024), Obakhume (2026), Jolo et al. (2022), and Musikavanhu et al. (2026).

5. Next Steps

The empirical findings of this comparative research and the associated econometric panel benchmarks point to four straightforward, practical policy directions that Guyana must undertake to manage its rapid resource expansion and prevent long-term hollowing out of its non-resource sectors:

Pacing Public Spending to Control Inflation: To avoid economic overheating and the domestic price increases often associated with rapid, resource-led expansion, the government should pace Natural Resource Fund transfers to match what the local economy can realistically absorb. In addition to careful budgeting, this study recommends establishing a separate, ring-fenced "Non-Oil Innovation" Fund offshore. This sub-fund would intentionally keep excess oil revenues out of the local money supply to prevent localised inflation, using those resources instead to provide credit guarantees and research matching grants exclusively to private, non-oil businesses, such as advanced agro-processing and domestic manufacturing. This strategy ensures that physical resource wealth is successfully converted into long-term technological innovation and private-sector growth.

Establishing Worker Safety Nets: Rather than relying on temporary construction booms to keep unemployment low, Guyana must build permanent, formal support systems for its workforce. Based on cross-country evidence showing that strong labour market institutions are critical for cushioning economic shocks, the state should establish a formal unemployment insurance system paired with practical skills-retraining programmes. These systems will protect local families during global oil price crashes, provide workers with transferable skills, and prevent the rigid structural unemployment and youth labour market stagnation historically observed in resource-dependent nations like Gabon.

Expanding Job Opportunities for Women: To address the severe gender labour gap, where male participation dominates and female youth unemployment remains acutely high, the state must move beyond general social grants and implement targeted incentives. Introducing statutory, gender-targeted wage subsidies for private, non-oil tradeable sectors, such as digital services, communications, and specialised manufacturing, will actively encourage businesses to hire young women. This targeted fiscal intervention will help dismantle the male-biased hiring patterns of the current infrastructure boom and support a more inclusive, balanced economy similar to the diversified baseline model of Costa Rica.

Recalibrating Local Content for Local Skills: To break the emerging "technical glass ceiling" where high-paying engineering and managerial roles are dominated by foreign nationals while

local workers are concentrated in lower-value support services, Guyana must update its Local Content Act. Following the lessons of other petrostates, the state should shift its focus from simple service contracts (such as catering, driving, and security) to mandating formal "Joint Venture Technology Transfers." Under this framework, multinational prime contractors would be required to establish structured training partnerships with local firms, legally tying their extraction licences to verified milestones for transferring skills and certified roles to native Guyanese professionals.

6. References

Aker, Ş. L., & Aghaei, I. (2019). Comparison of business environments in Oil-Rich MENA Countries: A Clustering analysis of economic diversification and performance. Emerging Markets Finance and Trade, 55(12), 2871–2885. https://doi.org/10.1080/1540496x.2018.1537185

Alkhathlan, K. A., Alkhateeb, T. T. Y., Mahmood, H., & Bindabel, W. A. (2020). Concentration of oil sector or diversification in Saudi economy: consequences on growth sustainability. Journal of Entrepreneurship and Sustainability Issues, 7(4), 3369–3384. https://doi.org/10.9770/jesi.2020.7.4(52)

Alley, I. (2018). Oil price and USD-Naira exchange rate crash: Can economic diversification save the Naira? Energy Policy, 118, 245–256. https://doi.org/10.1016/j.enpol.2018.03.071

Balza, L., Brearley, E., Clarke, D., & Gauto, V. (2020). Traversing a slippery slope: Guyana's oil opportunity. Inter-American Development Bank. https://doi.org/10.18235/0002622

Cheratian, I., Farzanegan, M. R., & Goltabar, S. (2019). The asymmetric impact of oil prices on unemployment in the MENA region. Review of Middle East Economics and Finance, 17(3), 175–204. https://doi.org/10.1515/rmeef-2021-0004

Corden, W. M., & Neary, J. P. (1982). Booming sector and de-industrialisation in a small open economy. The Economic Journal, 92(368), 825-848. https://doi.org/10.2307/2232670

Ferreira, G. (2009). The Expansion and Diversification of the Export Sector and Economic Growth: The Costa Rican Experience (Doctoral Dissertation, Louisiana State University). https://doi.org/10.2307/2232670

Flores, J. L. C. (2023). Usman, Z. 2022. Economic Diversification in Nigeria: The Politics of Building a Post-Oil Economy. Pensamiento Crítico, 28(1), 115–119. https://doi.org/10.15381/pc.v28i1.25725

Guyana Bureau of Statistics. (2024). Guyana Labour Force Survey Report Fourth quarter 2024. https://statisticsguyana.gov.gy/wp-content/uploads/2019/10/GLFS-2024-Bulletin.pdf

Hartwick, J. M. (1977). Intergenerational equity and the investing of rents from exhaustible resources. The American Economic Review, 67(5), 972-974. http://www.jstor.org/stable/1828079

Hvidt, M. (2020). Economic diversification and job creation in the Arab Gulf Countries: Applying a Value chain perspective. In The political economy of the Middle East (pp. 281–300). https://doi.org/10.1007/978-981-15-5728-6_11

International Monetary Fund. (2025). Guyana: 2025 Article IV Consultation-Press Release; Staff Report; and Statement by the Executive Director for Guyana. IMF Staff Country Reports, 2025(103), 1. https://doi.org/10.5089/9798229008860.002

Jolo, A. M., Ari, I., & Koç, M. (2022). Driving factors of economic diversification in Resource-Rich countries via panel data evidence. Sustainability, 14(5), 2797. https://doi.org/10.3390/su14052797

Jouili, T. A., & Khemissi, F. M. (2019). Impact of economic diversification on graduates' employment. International Journal of Advanced and Applied Sciences, 6(3), 35–39. https://doi.org/10.21833/ijaas.2019.03.006

Kaya, A., Tok, E., Koc, M., Mezher, T., & Tsai, I.-T. (2019). Economic Diversification Potential in the Rentier States Towards for a Sustainable Development: A Theoretical Model. Sustainability, 11, 911. https://doi.org/10.3390/su11030911

McDonald, L., & Üngör, M. (2021). New oil discoveries in Guyana since 2015: Resource curse or resource blessing. Resources Policy, 74, 102363. https://doi.org/10.1016/j.resourpol.2021.102363

Ministry of Finance Guyana. (2025). Mid Year Report - 2025. https://finance.gov.gy/wp-content/uploads/2025/09/Mid-Year-Report-2025.pdf

Musikavanhu, L., Gamariel, G., & Choga, I. (2026). Oil Prices, Labour Market Institutions, and Unemployment: Evidence from African Oil-Exporting Economies. Economies, 14(4), 103. https://doi.org/10.3390/economies14040103

Neffati, M., & Jbir, R. (2024). The impact of digitalisation and economic diversification on economic growth: evidence from Saudi Arabia. Technological and Economic Development of Economy, 30(5), 1510–1532. https://doi.org/10.3846/tede.2024.22105

Obakhume, K. A. (2026). Local content development and the resource curse in Nigeria: Comparative lessons and policy reform pathways. Social Sciences & Humanities Open, 13, 102291. https://doi.org/10.1016/j.ssaho.2025.102291

Ross, M. L. (2017). What do we know about economic diversification in Oil-Producing countries? SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3048585

Senadjki, A., Nee, A. Y. H., Nathan, T. M., Mapendo, J. J., & Djouahra, S. (2025). Employment Beyond oil: Structural drivers and institutional moderators in MENA countries. In Advances in Economics, Business and Management Research (pp. 337–359). https://doi.org/10.2991/978-94-6463-968-1_25

Tok, E., Koç, M., & D'Alessandro, C. (2020). Entrepreneurship in a transformative and resource-rich state: The case of Qatar. The Extractive Industries and Society, 8, 100708. https://doi.org/10.1016/j.exis.2020.04.002

World Bank. (2025). Guyana Country Profile. https://www.worldbank.org/ext/en/country/guyana

World Bank. (2026). Guyana Macro Poverty Outlook [Report]. https://thedocs.worldbank.org/en/doc/e408a7e21ba62d843bdd90dc37e61b57-0500032021/related/mpo-guy.pdf

Compliance as Catalyst: Digital-Sustainable Capability Building in a Border-Region Economy

Alejandra Rosales-Soto
CETYS University, Campus Tijuana, Mexico. Alejandra.rosales@cetys.mx

Verónica Mendoza-Ibarra
CETYS University, Campus Tijuana, Mexico. veronica.mendoza@cetys.mx

1. Introduction

Digitalization and sustainability increasingly operate as overlapping transformation pressures. Digital Transformation (DT) has become a strategic organizational process that affects operations, value creation, data use, and competitive positioning (Kraus et al., 2021, 2022). Sustainable Transformation (ST), in turn, requires firms to integrate environmental and social objectives into strategy, governance, and business models rather than treating sustainability as an isolated compliance activity (Geissdoerfer et al., 2017; Broccardo et al., 2023). Their simultaneous pursuit is increasingly conceptualized in the literature as a twin transition or digital-sustainable transformation, reflecting the potential complementarities between digital and sustainable capabilities (Guandalini, 2022).

The notion of dual transformation was originally articulated by Anthony, Gilbert, and Johnson (2017) as an organizational response to disruptive change. Their framework distinguishes between Transformation A, which repositions and strengthens the existing core business, and Transformation B, which creates a separate new growth engine, connected through a capabilities link that enables firms to leverage existing organizational assets while developing new trajectories. Rather than treating transformation as a single process, this perspective emphasizes the organizational challenge of managing two distinct but interconnected transformation pathways simultaneously.

In border-region economies, however, transformation takes place under distinctive institutional and market conditions. Firms may be closely connected to international production networks while simultaneously facing uneven access to innovation infrastructure, knowledge, finance, and local support. Tijuana, Mexico, provides a useful setting because firms operate next to the United States market and combine export-oriented manufacturing, services, commerce, and firms serving primarily local and regional markets.

The 148-firm database has already informed two related studies from the same research team. Encinas-Grijalva et al., (2024) designed and validated the self-diagnosis instrument used throughout this research stream and applied it to assess firms' overall readiness for dual transformation. That study found intermediate readiness levels for both DT and ST and identified strategy, organizational culture, organizational structure, and technical capabilities as the dimensions that most strongly explained readiness, with strong positive correlations observed across dimensions within each transformation type. Rosales-Soto *et al*. (2026) previously used this dataset to develop and apply the Dual Transformation Maturity Index (DTMI), mapping firms according to digital and sustainable maturity and identifying four transformation pathways. On average, that study found that sustainability transformation maturity exceeded digital

transformation maturity across the sample, pointing to uneven capability development across the two dimensions. That analysis revealed a counterintuitive pattern: export-oriented and formally certified firms did not systematically occupy the most advanced dual-transformation positions. The present article does not reproduce that mapping as its principal contribution. Instead, it builds on the earlier finding and asks a different question: how is combined exposure to export markets and formal quality certification associated with digital and sustainable capability building?

This study proposes the concept of compliance-driven capability building to describe a pattern in which firms' exposure to external requirements: through export markets and formal certification, is associated with stronger, rather than weaker, organizational capabilities for digital and sustainable transformation. The research question is: How is exposure to export markets and formal quality certification associated with DT and ST maturity among firms in a border-region economy, and do the observed patterns support a capability-building interpretation of compliance exposure? The objective is interpretive rather than causal: the cross-sectional evidence cannot establish that compliance causes higher transformation maturity.

2. Literature Review

2.1 Dual transformation as capability building

Digital Transformation (DT) is more than technology acquisition. It involves strategic alignment, organizational culture, data-driven decision making, employee learning, governance, and integration of information systems. Similarly, Sustainable Transformation requires firms to embed economic, environmental, and social considerations into strategy, processes, organizational responsibilities, knowledge management, and decision making. Research increasingly emphasizes that digital technologies can support sustainability through resource efficiency, traceability, information processing, and innovation (Ji et al., 2023; Lu et al., 2023; Song et al., 2024). The relevant question is therefore not simply whether firms adopt digital or sustainability practices, but whether they develop the organizational capabilities that allow both transformations to become embedded and mutually reinforcing.

Dynamic-capability research provides one organizational explanation: firms must sense technological and environmental changes, seize opportunities, and reconfigure resources as conditions evolve. From an innovation-and-development perspective, this points toward capability accumulation rather than adoption alone. Formal systems may provide routines and discipline, but transformation also requires learning, coordination, experimentation, and the capacity to adapt externally acquired practices to the firm's own strategic context.

2.2 External integration and the compliance-capability gap

Participation in international markets and formal certification can create important learning opportunities. Exporting exposes firms to demanding customers, technologies, and competitive benchmarks, while quality standards can institutionalize processes and improve reliability. Theoretical accounts differ, however, on whether this exposure translates into deeper organizational capability or remains confined to meeting external specifications, audit requirements, and delivery targets without broader transformation.

One strand of institutional theory would predict the opposite pattern. Meyer and Rowan's (1977) foundational account of decoupling holds that organizations often adopt formal structures to secure legitimacy while day-to-day activity remains loosely coupled from those structures, and empirical work on certifiable management standards shows that firms sometimes calibrate compliance symbolically, meeting external requirements without deeper substantive change (Christmann & Taylor, 2006; Boiral, 2007), particularly where compliance-focused routines compete with the organizational resources needed for capability development (Cao & Jayasinghe, 2024). A contrasting stream of research, however, documents substantive rather than symbolic effects of external market and certification exposure. Firm-level evidence on learning by exporting shows that exposure to foreign buyers and markets can transfer knowledge that raises innovation outcomes (Salomon & Shaver, 2005) and signaling-based accounts of certification find that certified firms grow faster after certification through channels other than immediate operational improvement, consistent with certification functioning as a credible signal that firms invest in to build and demonstrate capability (Terlaak & King, 2006).

Recent work on dual transformation similarly distinguishes immediate efficiency gains from longer-term capability development, showing that the two mechanisms can coexist but need not advance at the same rate. Alabduljabbar (2026) examines how Saudi Arabia´s Vision 2030 reforms: digitalization, localization and regulatory change, shape supply chain outcomes through two parallel pathways: direct, short-term efficiency and service-performance gains, and indirect, longer-term capability development mediated by organizational readiness as a dynamic capability. Using a mixed-methods design combining PLS-SEM survey data from 247 professionals with 20 interviews across 14 sectors, the study finds that the efficiency-oriented pathway accounts for the majority of observed effects (54%-65%), while capability development explains a smaller but substantial share (35%-46%), with logistics sectors favoring efficiency gains and manufacturing sectors favoring capability building. This evidence reinforces the view that dual transformation operates through coexisting rather than competing mechanisms, and its relative balance is conditioned by sectoral and institutional context, a pattern consistent with the heterogeneity observed among firms in Tijuana’s business ecosystem.

This study therefore uses compliance-capability gap as an interpretive concept rather than a predetermined causal mechanism. A persistent gap could become a compliance trap when externally oriented routines repeatedly satisfy immediate requirements without being converted into endogenous learning and transformation capabilities.

3. Methodology

This study conducts a secondary analysis of the 148-firm dataset previously used to map dual-transformation maturity in Tijuana (Rosales-Soto et al., 2026; Encinas-Grijalva, et al., 2024). Data were collected between 2022 and mid-2023 through a structured self-diagnosis questionnaire adapted from Encinas-Grijalva et al., (2024). Respondents occupied managerial or decision-making positions and represented firms of different sizes, sectors, export orientations, additional locations outside Tijuana, and certification statuses.

The instrument contains 24 five-point Likert items. Consistent with the original instrument (Encinas-Grijalva et al., 2024), items are scored so that lower values indicate stronger self-assessed alignment with the ideal transformation state described by each item. Items 1–12 measure Digital Transformation and items 13–24 measure Sustainable Transformation.

Firm-level DT and ST scores were calculated as the mean of the corresponding 12 items, and reverse-scored into a Maturity Index (6 minus the raw mean) so that higher values indicate higher maturity; this index is used throughout the results reported below. Internal consistency is high (DT Cronbach's $\alpha = 0.945$; ST $\alpha = 0.971$), consistent with Encinas-Grijalva et al. (2024).

To provide an analysis not reported in the previous DTMI paper, export status and formal quality certification were combined into an ordinal compliance-exposure indicator: 0 = neither exporter nor formally certified; 1 = exporter or formally certified; and 2 = both exporter and formally certified. This measure does not imply that exporting or certification is intrinsically negative; it captures increasing simultaneous exposure to two formal external-demand conditions. Mean DT and ST maturity were compared across the three groups using one-way analysis of variance (ANOVA). Effect sizes were estimated using eta squared (η^2), and Tukey HSD post-hoc tests were used to identify pairwise differences between exposure groups. A combined dual-transformation score, calculated as the mean of DT and ST, was used for a complementary rank-order association test. Because the study is cross-sectional and based on self-reported perceptions, results are interpreted as associations rather than causal effects.

4. Analysis of Results

4.1 Sample characteristics

The final sample comprised 148 firms operating in Tijuana, Mexico. Table 1 summarizes the sample's sectoral composition, firm-size distribution, export status, and certification status. Services firms account for the majority of the sample (57.4%), followed by manufacturing, wholesale trade, and retail trade. Most firms are micro or small, with just over a quarter reporting 51 or more employees. Non-exporters (71.6%) and non-certified firms (61.5%) form most of the sample, consistent with the compliance-exposure groupings examined in Section 4.2.

Table 1. Sample characteristics (N = 148)

Characteristic	Category	n	%
Sector	Services	85	57.4
	Manufacturing	23	15.5
	Wholesale trade	22	14.9
	Retail trade	18	12.2
Firm size (employees)	0–20 (micro)	49	33.1
	21–50	59	39.9
	51 or more	40	27.0
Export status	Exporter	42	28.4
	Non-exporter	106	71.6
Quality certification	Certified	57	38.5
	Not certified	91	61.5

Source: Authors' analysis based on the 148 firm survey database.

4.2 Compliance exposure and transformation maturity

The compliance-exposure grouping reveals a clear monotonic pattern in transformation maturity. Seventy-four firms are neither exporters nor formally certified (Low exposure), 49 meet one of the two conditions (Moderate exposure), and 25 are simultaneously exporters and certified (High exposure). As detailed in Table 2, DT maturity rises from 3.30 in the low-exposure group to 3.92

under moderate exposure and 4.08 under high exposure. ST follows the same pattern, increasing from 3.05 to 3.63 and 3.92, respectively, while the combined maturity index rises from 3.18 to 3.78 and 4.00.

To evaluate whether external-demand pressure differentiates organizational maturity, a three-step analytical strategy was implemented. First, a one-way analysis of variance (ANOVA) was conducted to determine whether mean maturity levels across the three exposure groups (Low, Moderate, and High) reflect statistically significant omnibus differences rather than random sampling variation, estimating effect sizes (η^2 and ω^2) to quantify the proportion of total variance explained by compliance pressure. Second, because the omnibus-test only detects overall group divergence, Tukey's Honestly Significant Difference (HSD) post-hoc comparisons were applied to prevent Type I error inflation and pinpoint which specific group transitions drive the differences. Finally, given that compliance exposure represents an ordered categorical construct, a non-parametric Spearman rank correlation (ρ) was conducted as a complementary robustness test to evaluate the monotonic strength and direction of this relationship without assuming strict interval scaling or normality.

Table 2. Dual-transformation maturity index by external compliance exposure

Exposure	Definition	n	DT Index (SD)	ST Index (SD)	Combined Index
Low	Neither	74	3.330 (0.98)	3.05 (1.12)	3.18 (0.95)
Moderate	Exporter or certified	49	3.92 (0.98)	3.63 (0.91)	3.78 (0.87)
High	Exporter + certified	25	4.08 (1.00)	3.92 (1.08)	4.00 (0.95)
		148			

Source: Authors' analysis based on the 148 firm survey databases.

Note. Maturity Index = 6 minus the mean raw item score (1–5 scale); higher values indicate higher digital (DT) or sustainable (ST) transformation maturity.

As shown in Table 3, one-way analysis of variance confirms that these differences across exposure groups are statistically significant for DT ($F(2,145) = 9.04$, $p < .001$), ST ($F(2, 145) = 8.32$, $p < .001$), and the combined index ($F(2, 145) = 10.43$, $p < .001$). Effect sizes were $\eta^2 = .111$ ($\omega^2 = .098$) for DT, $\eta^2 = .103$ ($\omega^2 = .090$) for ST, and $\eta^2 = .126$ ($\omega^2 = .113$) for the combined index, indicating that compliance exposure accounts for approximately 10% to 13% of the observed variance in organizational maturity. Figure 1 visually depicts this monotonic progression across all three dimensions.

Table 3. ANOVA and Tukey HSD post-hoc comparisons across compliance-exposure groups

Dependent Variable	Model Parameter / Comparison	Mean Diff.	SE	t	p	Effect Size (n^2/d)
DT Index	ANOVA Omnibus			F=9.04	<.001	n^2=.111
	Low vs. Moderate	-0.621	0.180	-3.44	.002	d=-0.63
	Low vs. High	-0.783	0.226	-3.46	.002	d=-0.80
	Moderate vs. High	-0.162	0.241	-0.67	.780	d=-0.17
ST Index	ANOVA Omnibus			F=8.32	<.001	n^2=.103
	Low vs. Moderate	-0.579	0.193	-3.00	.009	d=-0.55

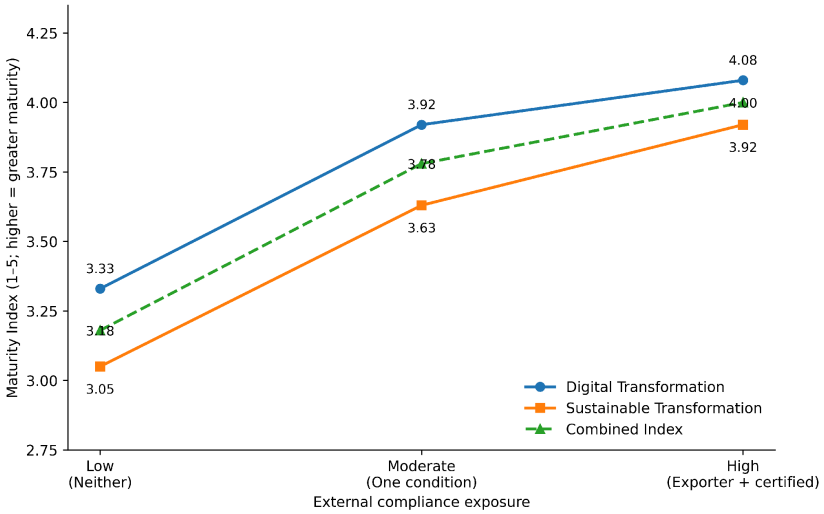
Dependent Variable	Model Parameter / Comparison	Mean Diff.	SE	t	p	Effect Size (n^2/d)
Combined Index	Low vs. High	-0.866	0.242	-3.57	.001	d=-0.83
	Moderate vs. High	-0.287	0.257	-1.12	.506	d=-0.27
	ANOVA Omnibus			F=10.43	<.001	n^2=.126
	Low vs. Moderate	-0.600	0.170	-3.54	.002	d=-0.65
	Low vs. High	-0.824	0.213	-3.87	<.001	d=-0.89
	Moderate vs. High	-0.224	0.227	-0.99	.584	d=-0.24

Source: Authors' analysis based on *Jamovi* output (emmeans and car packages). Degrees of freedom: df1=2, df_2 =145. p-values for pairwise comparisons are adjusted using Tukey's HSD test.

Tukey HSD post-hoc comparisons show that the low-exposure group has significantly lower maturity than the moderate-exposure group for DT (p=.002, d=−0.63), ST (p=.009, d=−0.55), and the combined index (p = .002, d = −0.65). Differences between the low- and high-exposure groups are also significant for DT (p = .002, d = −0.80), ST (p = .001, d = −0.83), and the combined index (p < .001, d = −0.89). In contrast, differences between the moderate- and high-exposure groups are not statistically significant for DT (p = .780, d = −0.17), ST (p = .506, d = −0.27), or the combined index (p = .584, d = −0.24).

Thus, although mean maturity increases monotonically across the three exposure levels, the post-hoc results reveal a clear threshold pattern: exposure to at least one external-demand condition (exporting or certification) substantively and significantly distinguishes firms from those facing neither requirement, whereas simultaneous exposure to both conditions yields incremental but not statistically distinct gains. As a complementary ordinal test, compliance exposure exhibits a positive and statistically significant association with the combined maturity index (Spearman ρ=0.361, p<.001, df=146). These results do not imply direct causality; rather, they demonstrate that, within this industrial sample, exposure to external regulatory and market pressures is systematically paired with higher self-assessed transformation capabilities.

Figure 1. Digital and sustainable maturity index by compliance exposure.



Source: Authors' analysis.

4.3 Compliance-driven capability building

The pattern is important because firms exposed to at least one external-demand condition report significantly higher self-assessed transformation maturity than firms exposed to neither condition. While the high-exposure group reports the highest mean maturity, its scores are not statistically distinguishable from those of the moderate-exposure group. This threshold pattern is consistent with a capability-building account of external integration: exposure to buyer requirements, international competition, formal standards, and third-party audits may be associated with stronger digital and sustainable transformation maturity.

Exporting firms operating within international production systems are exposed to demanding customers, foreign competitors, and technology transfer that can accelerate organizational learning, consistent with learning-by-exporting accounts of firm capability development (Salomon & Shaver, 2005). Certification can similarly function as more than a compliance cost: because certification credibly signals underlying organizational quality to customers and partners, firms may be motivated to invest in the substantive capabilities that certification is meant to signal, generating real, not merely symbolic, improvement (Terlaak & King, 2006).

Compliance, in this reading, is not a substitute for capability building but a potential channel through which organizational learning and upgrading may occur. For Tijuana's innovation ecosystem, this suggests that programs connecting certification and export support with managerial learning, digital integration, supplier development, university-industry collaboration, and sustainability innovation may reinforce a capability-building dynamic that export and certification exposure already appear to support.

The significant differences between firms with no exposure and those with at least one external-demand condition also point to a potential capability-exposure gap: firms outside export markets and formal certification systems may have less access to the learning pressures, benchmarks, and organizational routines associated with these environments. This does not imply that policy should simply increase regulatory requirements. Rather, export-readiness and certification instruments can be designed as learning infrastructures that broaden access to capability-building opportunities, particularly for firms currently outside these external-demand environments.

5. Concluding Remarks

This article extends the earlier DTMI mapping of Tijuana firms by examining a new question: whether exposure to export markets and formal quality certification corresponds with stronger digital and sustainable transformation maturity. The evidence shows a clear monotonic pattern in the predicted direction. Firms with neither condition report the lowest mean DT and ST maturity; firms with one condition occupy an intermediate position; and firms that are both exporters and certified report the highest mean maturity. However, Tukey HSD comparisons show that the statistically significant differences occur between firms with no external compliance exposure and those exposed to at least one condition, whereas the additional difference between moderate and high exposure is not statistically significant.

This result is consistent with compliance-driven capability building, but it does not prove that exporting or certification causes stronger transformation. External requirements associated with

export markets and formal certification may function as channels through which firms are exposed to demanding buyers, competitive benchmarks, and structured process requirements that, over time, may contribute to broader digital and sustainable transformation capability, consistent with learning-by-exporting and certification-signaling perspectives.

The implication for innovation and development policy is that participation in global markets and formal standards should be treated as a plausible capability-building lever, not merely a compliance cost. The results also suggest a potential capability-exposure gap affecting firms that neither export nor participate in formal certification systems. Programs that pair export and certification support with digital skills, data use, organizational learning, sustainability strategy, supplier development, and collaborative innovation may therefore help broaden access to the learning mechanisms associated with external-demand exposure. Rather than increasing compliance for its own sake, policy can design these instruments as learning infrastructures that support more inclusive digital and sustainable capability building. This is particularly relevant for regions such as Tijuana, where proximity to global markets creates opportunities for technological and organizational upgrading that may not be evenly distributed across the business ecosystem.

The study has three limitations. First, its cross-sectional design prevents causal inference; the direction of the association between compliance exposure and maturity cannot be established from these data alone. Second, the measures are based on managerial self-assessment. Third, the compliance-exposure indicator is intentionally parsimonious and captures only export participation and formal quality certification. Future research could test the compliance-driven capability-building proposition longitudinally, distinguish types and intensity of certification, incorporate export dependence and buyer relationships, and examine whether local innovation-system linkages further strengthen the capability-building dynamic observed here.

6. References

Alabduljabbar, S. (2026). Dual transformation pathways in supply chains: Linking national reforms to efficiency gains and capability development. Supply Chain Management: An International Journal, 31(7), 100–117. https://doi.org/10.1108/SCM-08-2025-0812

Anthony, S.D., Gilbert, C.G., & Johnson, M.W. (2017). Dual Transformation, how to reposition today's business while creating the future. Harvard Business Review Press. ISBN: 9781633692480

Boiral, O. (2007). Corporate greening through ISO 14001: A rational myth? Organization Science, 18(1), 127–146. https://doi.org/10.1287/orsc.1060.0224

Broccardo, L., Zicari, A., Jabeen, F., & Bhatti, Z. A. (2023). How digitalization supports a sustainable business model: A literature review. Technological Forecasting and Social Change, 187, 122146. https://doi.org/10.1016/j.techfore.2022.122146

Cao, Y., & Jayasinghe, M. (2024). 'Social compliance decoupling cascades' in global supply chains: A review of the implementation of labour codes. International Journal of Management Reviews, 26(3), 344–368. https://doi.org/10.1111/ijmr.12357

Christmann, P., & Taylor, G. (2006). Firm self-regulation through international certifiable standards: Determinants of symbolic versus substantive implementation. Journal of International Business Studies, 37(6), 863–878. https://doi.org/10.1057/palgrave.jibs.8400231

Encinas-Grijalva, M. S., Olivieri-Sangiacomo, F. A., Galván-Vela, E., et al. (2024). Business readiness for dual transformation: An analysis of business capabilities for digital and sustainable transformation. Discover Sustainability, 5, 164. https://doi.org/10.1007/s43621-024-00370-8

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The circular economy - A new sustainability paradigm? Journal of Cleaner Production, 143, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Guandalini, I. (2022). Sustainability through digital transformation: A systematic literature review for research guidance. Journal of Business Research, 148, 456–471. https://doi.org/10.1016/j.jbusres.2022.05.003

Ji, Z., Zhou, T., & Zhang, Q. (2023). The impact of digital transformation on corporate sustainability: Evidence from listed companies in China. Sustainability, 15(3), 2117. https://doi.org/10.3390/su15032117

Kraus, S., Durst, S., Ferreira, J. J., Veiga, P., Kailer, N., & Weinmann, A. (2022). Digital transformation in business and management research: An overview of the current status quo. International Journal of Information Management, 63, 102466. https://doi.org/10.1016/j.ijinfomgt.2021.102466

Kraus, S., Jones, P., Kailer, N., Weinmann, A., Chaparro-Banegas, N., & Roig-Tierno, N. (2021). Digital transformation: An overview of the current state of the art of research. SAGE Open, 11(3). https://doi.org/10.1177/21582440211047576

Lu, H. T., Li, X., & Yuen, K. F. (2023). Digital transformation as an enabler of sustainability innovation and performance. Technological Forecasting and Social Change, 196, 122860. https://doi.org/10.1016/j.techfore.2023.122860

Meyer, J. W., & Rowan, B. (1977). Institutionalized organizations: Formal structure as myth and ceremony. American Journal of Sociology, 83(2), 340–363. https://doi.org/10.1086/226550

Rosales-Soto, A., Mendoza-Ibarra, V., & Encinas-Grijalva, S. (2026). Modeling digital and sustainable innovation pathways in Tijuana's business ecosystem. LACCEI 2026. https://dx.doi.org/10.18687/LACCEI2026.1.1.752

Salomon, R. M., & Shaver, J. M. (2005). Learning by exporting: New insights from examining firm innovation. Journal of Economics & Management Strategy, 14(2), 431–460. https://doi.org/10.1111/j.1530-9134.2005.00047.x

Song, Y., Du, C., Du, P., Liu, R., & Lu, Z. (2024). Digital transformation and corporate environmental performance: Evidence from Chinese listed companies. Technological Forecasting and Social Change, 201, 123159. https://doi.org/10.1016/j.techfore.2023.123159

Terlaak, A., & King, A. A. (2006). The effect of certification with the ISO 9000 Quality Management Standard: A signaling approach. Journal of Economic Behavior & Organization, 60(4), 579–602. https://doi.org/10.1016/j.jebo.2004.09.012

CHAPTER III.

Governing Sustainability Transitions

Climate Investment Sequencing in Small Island Developing States: Jamaica's Climate Investment Strategy (2026–2040)

Omar Chedda
Ministry of Industry, Investment and Commerce, Jamaica, omar.chedda@gmail.com

1. Introduction

Climate investment in small island economies is often presented as a financing-gap problem. Yet which investments should precede others is equally important when infrastructure is interdependent, financing conditional, implementation capacity limited, and shocks alter fiscal space. Renewable generation may be poorly timed if the grid cannot integrate it; finance may be unusable if the pipeline, audit trail, or institutional mandate is unready. Timing is part of strategy.

Jamaica illustrates the stakes. The World Bank and Global Facility for Disaster Reduction and Recovery estimated direct physical damage from Hurricane Melissa, which hit Jamaica in October 2025, at US$8.754 billion, approximately 41% of 2024 gross domestic product (GDP), while the subsequent Planning Institute of Jamaica and Economic Commission for Latin America and the Caribbean assessment placed damage, losses, and additional costs at US$12.232 billion, or 56.7% of GDP; the two measure different scopes (Planning Institute of Jamaica, 2026; World Bank & Global Facility for Disaster Reduction and Recovery, 2025). Against this background, a proposed Climate Investment Strategy (CIS) recommends a modular US$6.5 billion full-ambition planning ceiling across energy, transport, water, coastal resilience, agriculture, public facilities, waste, and enabling systems. It is a candidate pipeline; financing is committed only after project-level evidence (Chedda, 2026).

This article asks how portfolio-level sequencing shapes what climate investments are feasible, financeable, and institutionally sustainable for small island developing states (SIDS). It argues that effective climate investment requires the ordered relaxation of constraints: foundational assets and institutions must be established before more complex investments can perform, financing instruments must be matched to readiness, and monitoring must be connected to rules that alter the portfolio when conditions deteriorate.

The article treats sequencing as the link between adaptation economics, climate public investment management, and SIDS political economy. It identifies the CIS's conditional decision tools - the External Financing and Delivery Trigger (EFDT) and the Partner/Instrument Fit scorecard (PIF) - as policy innovations because they convert changing risk evidence into transparent choices about timing, financing, and delivery. The sections that follow review the literature and method, analyse portfolio design and evidence, and draw implications for SIDS climate strategies.

2. Literature Review

Adaptation economics recognises uncertainty, irreversibility, distribution, and service continuity alongside conventional cost-benefit analysis. Well-designed early warning, resilient infrastructure, water management, and nature-based solutions can produce substantial benefits,

but returns depend on exposure, design, maintenance, institutions, and complementary investments (Global Commission on Adaptation, 2019; Hallegatte et al., 2019; Intergovernmental Panel on Climate Change, 2022). Investment order is important because one project's benefit may depend on whether an enabling system has already been strengthened.

Climate public investment management shifts attention from isolated projects to the institutions that plan, allocate, appraise, implement, and monitor a portfolio, integrating climate considerations across the public investment cycle (International Monetary Fund, 2025). This supports portfolio questions that project appraisal alone cannot answer: which investments enable others, which should be protected when the envelope tightens, and which require regulatory preparation before procurement.

SIDS political economy adds structural constraints. Small markets, concentrated trade, high import dependence, recurrent hazards, and limited administrative depth raise the cost of preparing and coordinating investment. External finance remains indispensable but carries debt, foreign-exchange, creditor, vendor, and conditionality risks. Eastern Caribbean evidence shows that adaptation needs cannot be separated from fiscal, data, and delivery constraints (Pant et al., 2023). Visible projects may also be favoured over enabling systems whose benefits emerge later (Mani & Mukand, 2007; Mullin & Hansen, 2023).

Recent adaptation frameworks emphasise iterative decisions. Uncertain hazards, technologies, prices, and financing conditions require pathways that preserve options and adjust as evidence improves, supported by decision points, monitoring indicators, and institutional responsibility. Physical risk, insurance availability, credit conditions, and public balance-sheet exposure can alter which measures remain feasible (Network for Greening the Financial System, 2024; Organisation for Economic Co-operation and Development, 2024). Conditional sequencing makes the circumstances for acceleration, substitution, refinancing, or deferral explicit.

Existing research explains why adaptation is valuable, public-investment institutions matter, and SIDS face distinctive constraints. It less often treats investment order as the mechanism connecting these domains; the rules governing order commonly remain implicit. The Jamaican case is useful because the CIS makes sequencing explicit across phases, financing layers, institutional responsibilities, and stress-response tools.

3. Methodology

The article uses a structured interpretive case study of Jamaica's proposed CIS, treated as a portfolio-level decision object that assigns investment lines to phases, identifies dependencies, differentiates financing instruments, and specifies corrective triggers. The underlying strategy used a hybrid costing method combining known pipeline costs, comparator unit costs, delivery-enabler allowances, and readiness- and dependency-based phasing.

The article examines the CIS through five pre-specified questions. Which investments are placed early, and what constraints are they intended to relax? How does the financing mix change with phase and risk condition? Which institutions and decision tools are required before scale-up? How does the strategy distinguish targets, screening weights, sensitivities, stress tests, and appraisals? And what action follows when monitoring indicates deteriorating conditions? Evidence was organised in a matrix covering dependency, phase, finance, governance, adaptive rule, and evidentiary status.

Quantitative claims were classified by evidentiary status rather than treated as equally reliable, on the boundary set out in Table 2. Damage figures were checked against the Global Rapid Post-Disaster Damage Estimation (GRADE) assessment and the Planning Institute of Jamaica update, and institutional claims against the February 2026 Auditor General audit.

The author prepared the CIS and is therefore analysing a strategy in whose development he participated. This positionality provides knowledge of the design logic but risks confirmation bias. The study addresses that risk through the pre-specified questions, explicit limitations on quantitative claims, separation of strategy content from external evidence, and no claims of implementation effectiveness. The views expressed are the author's and do not necessarily represent the Ministry of Industry, Investment and Commerce.

4. Analysis of Results and Discussion

4.1 Phasing and portfolio dependencies

The portfolio is organised into three non-overlapping periods: Phase I (2026–2030), Phase II (2031–2035), and Phase III (2036–2040). Their indicative planning envelopes are US$2.2 billion, US$2.8 billion, and US$1.5 billion, respectively. Phase I establishes system enablers, financeable resilience packages, and delivery institutions; Phase II scales investment through aggregation, blended finance, and a stronger pipeline of appraised projects; Phase III embeds climate considerations in fiscal, financial, procurement, and asset-management systems (Chedda, 2026). The sequence is modular: if finance is weaker than assumed, the envelope is right-sized while early warning, water, coastal protection, critical facilities, grid hardening, and delivery capacity are protected.

Energy shows the enabling logic most clearly. Grid modernisation and storage precede full renewable expansion because a storm-resilient network with adequate interconnection capacity is required to integrate variable generation, sustain water pumping and health facilities, and support transport electrification. Grid modernisation and storage, utility-scale renewables, distributed and rooftop solar, and transport electrification together represent 51.1% of the planning ceiling. This is a composition indicator rather than a priority ranking. Water, coastal, and agricultural investments add further dependencies: reliable water requires electricity, coastal ecosystems affect flood exposure and aquifers, and climate-smart agriculture depends on storage, irrigation, and extension capacity. These orderings draw on a comparator base of documented interventions in small island and Caribbean states, selected for hazard-profile similarity, documentation quality, and relevance to a specific line. Barbados’s documented use of water-loss reduction and reclaimed wastewater provides regional support for this ordering (Green Climate Fund, 2018; Inter-American Development Bank, 2024).

Phase I comprises 11 candidate packages, five of which are presented in Table 1. Their ordering reflects system readiness, low-regret resilience, citizen-visible benefits, and their capacity to enable the preparation and financing of later investments.

Separately, the strategy tests how the full portfolio would be prioritised if only US$3.25 billion were available. This constrained-funding scenario makes the protection rule observable. Early warning is retained in full; coastal resilience and programme management retain about four-fifths of their full allocations; water, critical facilities, and grid hardening remain substantial; and agriculture preserves lower-cost measures. Utility renewables, distributed solar,

and transport electrification are paced more sharply to private finance and readiness, while major waste-treatment assets are deferred although policy work continues. A tighter envelope therefore preserves the dependency logic and leaves deferred modules capable of restoration without redesigning the portfolio (Chedda, 2026).

Table 1. Selected packages from the 11-package Phase I candidate pipeline

Selected package	Phase I amount	Sequencing rationale	Default financing approach
Grid modernisation and storage	US$440m	Enables reliable power, renewable integration, water, health, and transport systems.	Concessional loans, domestic budget, and technical-assistance grants.
Water, wastewater, and reuse	US$396m	Non-revenue water reduction and verified savings precede larger storage and reuse investments.	Concessional loans, domestic resources, grants, and possible later refinancing.
Utility renewables and interconnection	US$330m	Rolling procurement is paced to grid headroom, land, safeguards, and interconnection readiness.	Private capital with guarantees or blended finance; concessional enabling works.
Public transport electrification	US$264m	Fleet procurement follows route planning, depot-power assessment, and an operating model.	Concessional and blended finance, guarantees, viability support, and insurance.
Early warning and disaster risk management	US$88m	Low-regret coverage and last-mile protocols protect lives and support risk-financing readiness.	Grants, domestic budget, and risk-transfer layers.

Source: Author's analysis based on Chedda (2026).

4.2 Finance, institutions, and diversification

The CIS separates finance by function and phase. Early investment relies principally on concessional loans, grants, domestic allocations, and policy-linked official finance, which lower costs and support project preparation. Scale-up finance includes thematic bonds, blended structures, guarantees, public-private partnerships, and debt-for-climate swaps, all of which become more credible once the state demonstrates appraised projects, measurable outputs, procurement capacity, and auditable monitoring. Contingent credit, parametric insurance, and catastrophe cover protect fiscal space after a disaster.

Institutions make these layers usable, and the CIS grounds its design in a documented diagnosis. The February 2026 Auditor General performance audit found inconsistent coordination, procurement and staffing delays, incomplete measurement and reporting, and no climate-finance classification or central repository (Auditor General's Department, 2026). Under the CIS, the Climate Finance Unit being established in the Ministry of Finance and the Public Service would maintain the financing register, administer climate budget tagging, coordinate proposals and the pipeline, undertake PIF reviews, and support annual climate accounts, while

the proposed National Climate Trust Fund would pool and blend resources as the portfolio expands.

Sequencing also governs the interface with post-Melissa reconstruction. The National Reconstruction and Resilience Authority is the statutory coordinator for major reconstruction and resilience projects (Office of the Prime Minister, 2026b). The Government announced a coordinated multilateral financing package of up to US$6.7 billion (Office of the Prime Minister, 2026a). Under the CIS, however, none of that amount is counted as secured financing unless matching projects, approvals, financing terms, and drawdown schedules are reconciled with the single project register (Chedda, 2026). This prevents apparent post-disaster abundance from being mistaken for portfolio funding.

Diversification decision rules extend the principle to public balance-sheet exposures and strategic networks. Proposed comply-or-explain limits cap concentration among creditors, vendors, markets, and instruments - no single external creditor above 30% of public external debt and no single vendor above 50% in critical energy or digital systems - alongside annual disclosure of public-private partnership fiscal risks. The Shelter Principle assesses whether a partner or instrument strengthens economic buffers, access to alliances and international rule-making, and societal connections through diaspora, remittance, and skills networks. These dimensions carry a quarter of the PIF weight.

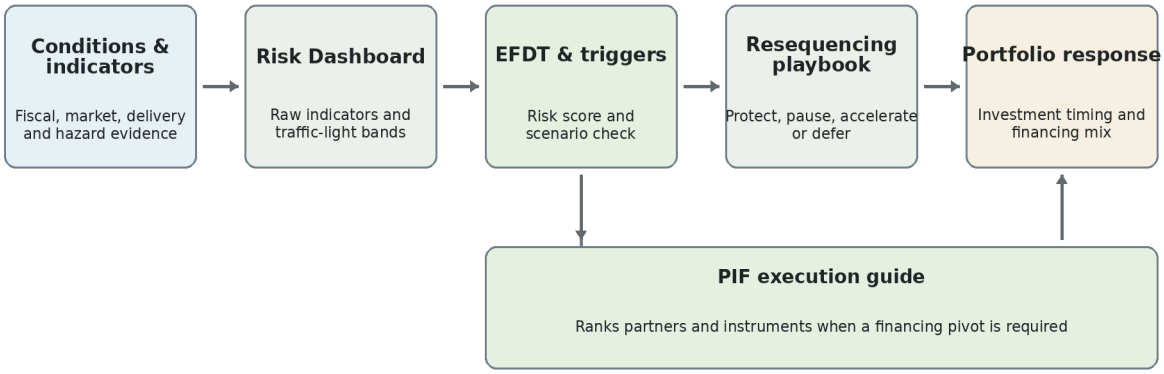
4.3 Conditional sequencing as policy innovation

The EFDT and PIF are the CIS's most distinctive policy innovations. The EFDT combines three normalised sub-scores - exposure, resilience risk, and governance risk, weighted 0.4, 0.4, and 0.2 - into a 0-100 gauge where higher values are worse. Green scores below 30 support routine delivery, while Amber scores from 30 to 50 require vigilance and preparatory adjustment. A Red EFDT score above 50, or an increase of at least 10 points from the prior quarter, counts as one trigger condition; a resequencing playbook is activated only when at least two conditions specified for the relevant scenario are met. An illustrative stress test moves the score from 41.8 to 52.0 after a major hurricane and tighter financing conditions, crossing into Red. In the worked playbook, US$220 million shifts toward storage, water, and coastal resilience, while the grant share rises by 10 percentage points.

Exposure indicators - import dependence and export, creditor, and tourism concentration - move slowly and set the structural position. Resilience and governance risk respond within a quarter to reserve drawdowns, interest-burden shifts, logistics failures, and permitting delays; in the worked scenario, exposure moves 0.6 points while resilience risk moves 17.3. The EFDT level therefore reflects structural vulnerability, while quarter-to-quarter changes signal shifts in current conditions. The fastest-transmitting channels are external-financing tightening, trade and logistics disruption, and tourism-demand shocks.

The PIF guides execution once a decision point is reached. Major grants, loans, guarantees, swaps, bonds, and public-private partnerships are scored against environmental and social alignment, financial terms and debt sustainability, additionality and mobilisation, governance and implementation capacity, shelter quality, network effects, and strategic autonomy. Passing requires a weighted score of at least 3.5 out of 5, no criterion below 2.5, and financial terms not below 3.0; project approval also requires fiscal, appraisal, financing-status, and overlap checks. The EFDT indicates when to pivot; the PIF helps determine how and with whom. Figure 1 presents the operating chain.

Figure 1. Conditional sequencing from risk evidence to portfolio action



Source: Author's construction based on Chedda (2026).

This is governance innovation: the tools connect monitoring to thresholds, playbooks, financing choices, and audit trails. They reduce ad hoc judgement while preserving contextual discretion and require decision-makers to explain why an investment is accelerated, protected, substituted, refinanced, or deferred.

The reporting cycle is essential to that claim. The CIS proposes a quarterly internal dashboard, a six-month early-warning note, annual public climate accounts, Auditor General review every two to three years, and a five-year strategy review aligned with Jamaica's climate commitments. Dashboard compilation is assigned to existing climate-policy and planning institutions rather than a new delivery body, and PIF matrices and financing-status evidence accompany annual reporting. Without that reporting cycle, the EFDT would be only an index and the PIF only a checklist.

4.4 Screening, expected annual loss (EAL) sensitivity, event stress testing, and appraisal

The current value-for-money framework deliberately avoids a portfolio benefit-cost ratio. Relative sector factors are ordinal planning weights under low, central, and high delivery conditions, each normalised to 100 across the portfolio so that relative priority can be compared without reading a factor as avoided dollars per dollar invested. Early warning and disaster risk management, for example, draws 12.4% of the central-case index points while accounting for 3.8% of the envelope. The factors inform ordering; they cannot establish net benefits or replace appraisal.

The probabilistic baseline begins with the tropical-cyclone EAL of approximately 0.9% of GDP estimated by the Inter-American Development Bank and cited in the GRADE assessment, equivalent to US$192.2 million a year on the strategy's US$21.35 billion 2024 GDP base. The present value of 15 equal annual losses at a 5% real discount rate is approximately US$1.995 billion. What 15%, 25%, or 30% of that EAL would represent is then reported as present values of approximately US$299.2 million, US$498.6 million, and US$598.4 million. These are sensitivities to the share of EAL affected by the portfolio, not forecasts of realised benefits (Chedda, 2026). Table 2 sets out the evidentiary boundary.

Table 2. Evidentiary status of the CIS value-for-money components

Component	Permitted interpretation	Not permitted
US$6.5billion envelope	Full-ambition, modular planning ceiling.	Committed expenditure or approved programme.
Sector screening	Ordinal comparison of relative priority within each scenario.	Avoided dollars per dollar invested or a portfolio benefit-cost ratio.
Cyclone EAL sensitivity	Discounted sensitivity to the illustrative share of EAL affected.	Forecast of realised portfolio benefits.
Melissa event test	Separate one-event fiscal stress and resequencing sensitivity.	Addition to EAL or to the other Melissa damage baseline.
Project appraisal	Without- and with-project loss distributions; incremental benefits; lifecycle capital and operation and maintenance costs; residual risk; distributional effects; overlap controls; 3%, 5%, and 7% discount-rate tests.	Approval based only on portfolio screening or event-scale estimates.

Source: Author's analysis based on Chedda (2026), Annex 2.

A separate Melissa-scale event test supports fiscal preparedness and resequencing. It applies illustrative 15%, 25%, and 30% reductions independently to the US$8.754 billion GRADE estimate of direct physical damage and the US$12.232 billion damage-and-loss assessment. The two baselines answer different questions and are never added to each other or to EAL. The event test shows the order of magnitude that a severe shock could place at risk; it does not assign a probability or claim that the portfolio would deliver the selected reduction.

For each major project, the CIS requires a probability-consistent lifecycle appraisal identifying the without-project and with-project loss distributions, incremental benefits, capital and operating costs, residual risk, distributional effects, and overlap with connected investments. Discount rates of 3%, 5%, and 7% must be tested. The principal benefit stream must fit the project: resilience investments may emphasise avoided disruption, while energy, transport, health, or ecosystem projects may require fuel, foreign-exchange, travel-time, health, or environmental benefits. This boundary prevents a planning tool from becoming a substitute for evidence needed at procurement.

5. Findings and implications

Three findings follow. First, sequencing connects benefits to preconditions: grid readiness affects renewables, water, health, and transport; institutional readiness affects access to complex finance; and maintenance and data systems affect whether benefits persist. Second, sequencing links finance to credibility: market-facing capital becomes usable as appraisal, procurement, monitoring, and delivery capability improve. Third, conditional sequencing gives political economy an operational form: pre-agreed rules can protect less visible enabling investments

when fiscal stress, electoral incentives, or emergency reallocations would otherwise displace them.

Citizen-facing outcomes reinforce this political economy. Phase I is intended to demonstrate lower outage frequency, more dependable water in drought-prone areas, improved mobility on selected corridors, broader warning coverage, and stronger shelter and clinic continuity, while building green skills and opportunities for smaller enterprises. These are directional outcomes, but visible service gains can build support for investments whose benefits mature later. Equity also affects durability: if costs, relocation burdens, or access to new services are distributed unfairly, the transition can lose legitimacy even where aggregate resilience improves.

The framework also has limits. A well-designed sequence cannot ensure implementation, financing, maintenance, or public trust. The EFDT depends on timely data and agreed thresholds, the PIF on candid scoring and disclosure, and institutions on authority, staffing, and coordination. Comparable practices show that key design choices are not unique to Jamaica: parametric reef insurance in Quintana Roo links funding to a trigger (The Nature Conservancy, 2018), while Fiji's Climate Change Act places curriculum integration and relocation provisions in statute (Government of Fiji, 2021). Transferable lessons are to make dependencies explicit, classify evidence correctly, protect specified investments under constraint, and connect monitoring to documented choices.

6. Concluding Remarks

Portfolio sequencing should be treated as a distinct analytical category in SIDS climate investment. Jamaica's CIS shows how investment dependencies, financing conditions, diversification design, and state capacity can be integrated into a phased decision system. Its US$6.5 billion ceiling expresses ambition, but the more original contribution lies in the rules and institutions intended to govern that ambition.

Conditional sequencing is the core policy innovation. The EFDT turns changes in fiscal, market, governance, delivery, and hazard conditions into a signal about when to pivot, and the PIF turns that signal into a structured comparison of instruments and partners. Screening weights, EAL sensitivity, and event stress testing support different planning judgements, while project appraisal remains the approval standard.

Future research should test whether the tools are used in practice, whether early enabling investments improve access to later finance, and whether citizen-visible Phase I outcomes sustain political support for long-run adaptation. For small, open, shock-prone economies, climate strategy is more than a financing issue. It is a question of what investments must be made first, under which conditions, and according to which accountable decision rule.

7. References

Auditor General's Department. (2026). *Jamaica's progress towards implementation of key climate change adaptation actions and plans* [Performance audit report]. https://auditorgeneral.gov.jm/wp-content/uploads/2026/02/CCAA-Final-Report-Website-Version.pdf

Chedda, O. (2026). *Climate investment strategy (2026–2040)* [Unpublished strategy paper].

Global Commission on Adaptation. (2019). *Adapt now: A global call for leadership on climate resilience*. World Resources Institute. https://gca.org/reports/adapt-now-a-global-call-for-leadership-on-climate-resilience/

Government of Fiji. (2021). Climate Change Act 2021 (Act No. 43 of 2021). https://fijiclimatechangeportal.gov.fj/legislation/climate-change-act-2021-an-act-to-establish-a-comprehensi

ve-response-to-climate-change-to-provide-for-the-regulation-and-governance-of-the-national-response-to-climate-change-to-introduce-a-system/

Green Climate Fund. (2018). *Water sector resilience nexus for sustainability in Barbados (WSRN S-Barbados)* [Funding proposal FP060]. https://www.greenclimate.fund/document/gcf-b19-22-add02

Hallegatte, S., Rentschler, J., & Rozenberg, J. (2019). *Lifelines: The resilient infrastructure opportunity*. World Bank. https://doi.org/10.1596/978-1-4648-1430-3

Inter-American Development Bank. (2024). *Barbados climate resilient South Coast water reclamation project* (Project BA-L1063). https://www.iadb.org/en/project/BA-L1063

Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. Cambridge University Press. https://doi.org/10.1017/9781009325844

International Monetary Fund. (2025). *C-PIMA handbook: Climate-Public Investment Management Assessment*. https://doi.org/10.5089/9798400294105.071

Mani, A., & Mukand, S. (2007). Democracy, visibility and public good provision. *Journal of Development Economics, 83*(2), 506–529. https://doi.org/10.1016/j.jdeveco.2005.06.008

Mullin, M., & Hansen, K. (2023). Local news and the electoral incentive to invest in infrastructure. *American Political Science Review, 117*(3), 1145–1150. https://doi.org/10.1017/S0003055422001083

The Nature Conservancy. (2018, March 8). *Insurance for coral reef restoration*. https://www.nature.org/en-us/what-we-do/our-insights/perspectives/business-to-the-rescue--insurance-for-reef-restoration/

Network for Greening the Financial System. (2024, November). *Conceptual note on adaptation*. https://www.ngfs.net/sites/default/files/medias/documents/ngfs_conceptual_note_on_adaptation.pdf

Office of the Prime Minister. (2026a, April 15). *Government tables National Reconstruction and Resilience Authority Bill*. https://opm.gov.jm/government-tables-national-reconstruction-and-resilience-authority-bill/

Office of the Prime Minister. (2026b, May 27). *NaRRA bill now law as government advances national reconstruction programme*. https://opm.gov.jm/narra-bill-now-law-as-government-advances-national-reconstruction-programme/

Organisation for Economic Co-operation and Development. (2024). *Accelerating climate adaptation: A framework for assessing and addressing adaptation needs and priorities* (OECD Economic Policy Papers No. 35). OECD Publishing. https://www.oecd.org/en/publications/accelerating-climate-adaptation_094c310d-en.html

Pant, R., Peard, A., Thacker, S., Jaramillo, D., Russell, T., & Hall, J. W. (2023). *Estimating investment needs for climate adaptation in the Eastern Caribbean*. Oxford Infrastructure Analytics.

Planning Institute of Jamaica. (2026, March). *Hurricane Melissa damage and loss assessment update* [Quarterly press briefing speaking notes]. https://www.pioj.gov.jm/wp-content/uploads/2026/03/DGs-QPB-30_3-Speaking-Notes.pdf

World Bank & Global Facility for Disaster Reduction and Recovery. (2025). *Global rapid post-disaster damage estimation (GRADE) report: Hurricane Melissa 2025 Jamaica*. https://www.gfdrr.org/sites/default/files/publication/GRADE%20Jamaica_FIN.pdf

Modelling an Integrated Waste-to-Energy PPP for Jamaica

Omar Chedda
Ministry of Industry, Investment and Commerce, Jamaica, omar.chedda@gmail.com

1. Introduction

Jamaica's municipal solid-waste system presents a linked development challenge. The country generates approximately 1.5 million tonnes of solid waste each year, but disposal continues to depend heavily on open dumps rather than fully engineered sanitary landfills. The Riverton City and Retirement legacy disposal sites, located in St. Andrew and St. James, respectively, have long outlived their design lives and experience recurrent fires, smoke and odour. Together with collection constraints, low levels of separation and recycling, and the absence of a modern residue-management system, these conditions impose environmental, health and productivity costs. The 2022 national waste-characterisation study also found that organics account for about 39.7% of the municipal waste stream, followed by plastics, cardboard, paper and other materials (Development Bank of Jamaica [DBJ], 2022). The Auditor General's Department (2022) separately identified persistent weaknesses in the regulation, coordination, collection and disposal functions of the National Solid Waste Management Authority (NSWMA).

Waste-to-energy (WtE) is therefore relevant to Jamaica, but only if treated as part of a wider reform encompassing collection, transfer, materials recovery, energy recovery from residual waste and final disposal. A stand-alone power-plant procurement would leave the underlying waste-system failures unresolved and could create new fiscal, environmental and feedstock risks. Electricity planning also imposes a demanding test. Jamaica's updated Integrated Resource Plan (IRP) retains WtE among the candidate resources but assigned it no capacity in the preferred portfolio, describing it as not competitive on the available power-sector data and calling for better technical and economic information before future consideration (Ministry of Science, Energy, Telecommunications and Transport [MSETT], 2024).

This article asks three questions. First, what WtE configuration is technically realistic and compatible with Jamaica's waste hierarchy and electricity system? Second, under what commercial and financial conditions could a representative 65 megawatt (MW) integrated WtE public-private partnership (PPP) reach financial close and achieve robust debt-service coverage by Operating Year 4? Third, what legal, regulatory, environmental, social and PPP-design measures would be required to implement it responsibly? The contribution is an integrated decision framework for a small island developing state. The framework connects waste composition and plant scale to project-finance performance, regulatory sequencing and public-interest safeguards. The following sections review the relevant literature, explain the methodology, present the results and draw out their implications for sustainable development.

2. Literature Review

Integrated solid-waste management and circular-economy research places prevention, reuse and recycling ahead of energy recovery and final disposal. OECD (2019) reviews show that effective circular-economy systems combine clear institutional responsibilities, reliable data, economic instruments, infrastructure finance and markets for recovered materials. In that framework, WtE

is not a substitute for waste reduction or recycling. Brunner and Morf (2025) nevertheless argue that modern WtE can perform a residual-waste and final-sink function when it destroys hazardous organic substances, recovers energy and metals, and operates with stringent pollution control. The relevance of that argument to Jamaica depends on whether the facility is sized for the residual stream after feasible diversion rather than being protected from future recycling gains.

The economic literature is more guarded. Dijkgraaf and Vollebergh (2004) demonstrate that comparisons between incineration and landfilling are highly sensitive to private costs, energy recovery and the valuation of environmental externalities, and Tait et al. (2025) similarly find that outcomes vary with capital and operating costs, waste composition, emissions controls and community acceptance.

According to PPP best practice, risks should be assigned to the party best able to control or absorb them. The Global Infrastructure Hub's WtE guidance identifies planning, construction, technology, waste quantity and quality, electricity offtake, payment, environmental and change-in-law risks as central to contract design (Global Infrastructure Hub, 2020). Private partners can ordinarily manage engineering, construction and operational performance, while government is often better placed to manage legal reform, public approvals, waste-flow enforcement and the credit quality of public payment obligations. In small island settings these standard categories intersect with scale, hurricane exposure, limited disposal alternatives, foreign-exchange volatility and constrained regulatory capacity.

Island experience narrows these general findings. Singapore operates large-scale incineration as core waste-management infrastructure rather than as a stand-alone power project: controlled delivery, storage bunkers large enough to smooth fluctuations in supply, bunker air management to contain odour, and continuous emissions monitoring that sustains regulatory credibility (National Environment Agency, 2026). The H-POWER facility on O'ahu illustrates a second pathway, in which energy recovery is financed and governed as a waste-disposal necessity with an electricity co-benefit; pairing dependable waste delivery with a firm offtake insulates the project from the two risks that compound in small systems, merchant price volatility and variable waste flows (Hawaiian Electric, n.d.). Mauritius supplies the cautionary case. The proposed incinerator at La Chaumiere attracted sustained public mobilisation and legal challenge in 2009, centred on dioxin exposure and on a waste stream with high organic content. It did not proceed, and the country instead advanced landfill-gas recovery at Mare Chicose, a less contested route that builds institutional capacity while wider reforms mature (Ackbarally, 2009).

These cases also mark the limits of transferability. Much of the Northern European business case for WtE rests on selling heat into district-heating networks and, in some jurisdictions, on importing waste to keep plants fully utilised (Nordic Council of Ministers, 2024). This business model would not be applicable or feasible for Jamaica. However, lessons can be learned from the institutional package, comprising enforceable flow control, collection performance, credible emissions regulation and enforcement, and a settled downstream solution for ash and residues. In addition to technical compliance, social legitimacy must also be considered. Community concerns about siting, traffic, local air quality and unequal exposure can determine whether approvals remain durable (Tait et al., 2025), and Jamaica's experience at Riverton City and Retirement makes transparent monitoring and enforceable remedies especially important.

3. Methodology

The study uses a mixed-methods, decision-oriented assessment designed to support policy and investment choices. The evidence base combines Jamaican waste and electricity data, project-finance modelling, legal and institutional review, and international benchmarks. Waste quantities and composition are drawn principally from the 2022 national characterisation study and public reports on the operation of the waste system. Power-sector assumptions are tested against the Integrated Resource Plan, while the approvals analysis reviews the National Solid Waste Management Act, environmental impact assessment (EIA) requirements, generation licensing, procurement and PPP processes (Auditor General's Department, 2022; DBJ, 2022; MSETT, 2024; National Environment and Planning Agency [NEPA], 2007).

The technical model begins with annual waste tonnage and a range of lower heating values. It estimates the thermal input required by a 65 MW plant and adjusts output for availability, internal electricity use and conversion efficiency. This provides an order-of-magnitude test of feasible plant scale and shows how collection performance, organics diversion and waste quality affect energy yield. Moving-grate mass-burn technology is assessed as the reference option for mixed residual municipal solid waste because it has a substantial operating record and can tolerate more heterogeneous feedstock than less mature thermal alternatives. Anaerobic digestion, landfill-gas capture and specialised pilots are assessed as complements for distinct waste fractions.

The financial model is a five-year operating and cash-flow model in United States dollars, supported by a longer project-life valuation. It incorporates total funding requirements, operating costs, working capital, maintenance, debt service and four potential revenue streams: power sales, gate fees, metals recovery and modest renewable-certificate income. The representative debt package comprises US$330 million in two tranches, one senior commercial and one concessional, with a 20-year tenor, interest-only treatment in Year 1 and level annual debt service thereafter. The model calculates cash flow available for debt service (CFADS), debt-service coverage ratios (DSCRs), project and equity internal rates of return (IRRs), and net present values (NPVs). Sensitivity tests vary the power tariff, gate fee, plant utilisation, throughput and capital cost.

A parallel institutional review maps the environmental, planning, generation-licensing, procurement, PPP and contractual steps that must converge at financial close. Critical-path reasoning identifies approvals that can delay the whole transaction, while international risk-allocation guidance and European best-available-technique conclusions provide comparators for contract and emissions-control design (European Commission, 2019; Global Infrastructure Hub, 2020). The results remain indicative. Waste composition, site conditions, bidder prices, exchange and interest rates, tax treatment, procurement outcomes and the final environmental assessment can materially change the case. The model should therefore be refreshed before tender, after environmental studies, at preferred-bidder stage and before financial close.

4. Analysis of Results

4.1 Technical configuration and system fit

The analysis supports a central 65 MW moving-grate facility as a plausible anchor asset, but not as the whole waste strategy. The design basis is approximately 850,000 tonnes per year,

consistent with the integrated solid-waste public-private partnership under preparation by the DBJ (DBJ, n.d.). The operating model is more conservative during ramp-up: throughput reaches approximately 762,000 tonnes in Year 4 and 807,000 tonnes in Year 5. At an 85% capacity factor, Year-4 net output is approximately 484 gigawatt-hours, equivalent to roughly a tenth of national electricity demand. This is dispatchable electricity, but only the portion attributable to the biogenic fraction of the waste stream should be classified as renewable.

The anchor plant is viable only as part of a multi-asset system. Required supporting investments include transfer stations and improved collection routes, grid interconnection, industrial water and wastewater systems, an engineered landfill for residual waste, and a secure ash monofill. These are operational necessities. Delivery should also be phased. Collection and transfer first, the central hub and engineered landfill second, and any western satellite only once waste-flow data justify it. Combustion may leave approximately 15–25% of input mass as bottom ash, air-pollution-control residues and other material requiring recovery, treatment or secure disposal (U.S. Environmental Protection Agency [EPA], 2026).

The 39.7% organic share creates both opportunity and risk. Wet organics lower effective calorific value and can reduce combustion efficiency. Separate collection and anaerobic digestion are better suited to food waste from markets, hotels, institutions and agro-processing, while landfill-gas capture can address methane from legacy cells. Materials recovery should remove recyclable metals and other viable fractions before or after combustion. Gasification and refuse-derived-fuel pilots should proceed only with demonstrably consistent feedstock and credible offtakers. This portfolio approach preserves the waste hierarchy and reduces the risk that a long-term minimum-tonnage commitment will crowd out future recycling. Sizing should be aligned with the plastics ban, the deposit-refund scheme and the expansion of Recycling Partners of Jamaica, so that capacity reflects realistic post-diversion tonnages.

4.2 Financeability and risk allocation

Table 1 distinguishes project-level capital cost from total funding uses, and lender coverage from equity attractiveness. Lenders and investors ask different questions of the same cash flows: whether debts can always be paid, and whether what remains rewards the risk. Total project and engineering capital is approximately US$632 million. Debt fees and a six-month debt-service reserve increase total uses to approximately US$657.2 million. The model assumes US$330 million in debt and US$327.2 million in equity.

Table 1. Indicative pre-tax financeability results for the integrated 65 MW WtE project

Metric	Indicative result	Interpretation
Total funding uses	US$657.2m	US$632.0m project cost, US$9.9m debt fees and US$15.3m debt-service reserve
Funding structure	US$330.0m debt; US$327.2m equity	Debt and equity are approximately balanced
Year-4 operations	Revenue US$131.81m; operating expenditure (OPEX) US$49.91m	Operating performance strengthens after ramp-up
Year-4 debt service	CFADS US$73.80m; debt service US$30.59m	Substantial lender headroom in the base case
DSCR pathway	0.91 / 1.04 / 2.41 / 2.76	Years 2–5; early years require distribution controls and liquidity protection
Project return	IRR 10.84%; NPV US$132.29m	Exceeds the modelled 9% project discount rate
Equity return	IRR 12.67%; NPV -US$43.11m	Below the modelled 14% equity hurdle

Source: Author's calculations based on the project-finance assumptions described in Section 3.

The results support a precise conclusion. The model reaches strong steady-state debt-service coverage by Year 4, when CFADS of US$73.8 million covers annual debt service of US$30.59 million 2.41 times. Bankability at financial close nevertheless depends on fully funding or restructuring the ramp-up shortfalls. In Operating Year 1, CFADS of US$5.03 million falls below interest-only debt service of US$22.25 million, and the six-month debt-service reserve of US$15.29 million would not fully cover the resulting gap. DSCR is also 0.91 in Year 2 and only 1.04 in Year 3. The financing structure therefore requires interest capitalisation, a larger liquidity reserve, sponsor support or more strongly sculpted debt. Once strong coverage is achieved, it is reasonably durable: single-variable tariff, gate-fee or operating stresses reduce Year-4 DSCR to 2.14–2.26, still well above the modelled 1.20 minimum threshold. The fragility lies in funding the ramp-up years.

However, the investor case must be assessed separately. The pre-tax project return exceeds the modelled 9% project discount rate, but the base-case equity return of 12.67% remains below the 14% equity hurdle. Because the base case already assumes a concessional tranche, the residual gap must be closed by a modestly stronger revenue floor, a longer tenor, deeper concessionality or a carefully calibrated blend, without transferring excessive risk to taxpayers or waste-service users.

The adjustments required are modest. An additional US$0.005 per kilowatt-hour from Operating Year 4 is worth approximately US$2.4 million a year at 484 gigawatt-hours, and an additional US$3 per tonne on the gate fee approximately US$2.3 million a year at 762,000 tonnes. Either lever, or a light blend of the two alongside a longer tenor or deeper concessionality, lifts equity returns towards the hurdle while leaving Year-4 coverage above 1.8 times. The Inter-American Development Bank has already supported studies and plans for the PPP business case through a US$800,000 technical-cooperation operation (Inter-American Development Bank, 2020). The remaining questions are: who pays the increment, and on what evidence of value for money.

The viable revenue package has four components: electricity sales under a long-term power purchase agreement (PPA), an indexed gate fee, metals recovery, and limited renewable-certificate or carbon income. The model's indicative Year-4 terms are a blended power price of about US$0.18 per kilowatt-hour, a gate fee of about US$50 per tonne in 2025 dollars and metals revenue of about US$8 per tonne. Carbon income should remain outside the base case. Article 6 transfers require host-country authorisation, robust monitoring, corresponding adjustments and reporting, while voluntary markets add price and eligibility uncertainty (United Nations Framework Convention on Climate Change [UNFCCC], 2025).

Revenue levels alone are insufficient. Enforceable flow control, a guaranteed minimum tonnage mechanism, one clearly identified public waste-payment counterparty, certified weighing, quality rules, gate-fee indexation and payment security are necessary to make the cash flows bankable. Construction and performance risk should sit with the private party under fixed-price, date-certain and performance-backed arrangements. Government should retain only those risks it can manage more efficiently, including legal reform, public approvals and enforcement. The contract suite must also allocate foreign-exchange, interest-rate, force-majeure and hurricane-resilience risks explicitly and provide for the funded closure, remediation and long-term aftercare of legacy disposal sites. Gate-fee commitments, guarantees and shortfall payments must be costed, disclosed and controlled as contingent fiscal liabilities.

4.2 Regulatory, environmental and social conditions

The power-sector constraint is binding. The IRP assigned zero capacity to WtE in the preferred portfolio because the available option was not competitive, and it noted that the data were insufficiently comprehensive for candidate modelling (MSETT, 2024). A candidate listing is therefore not a capacity award, and a WtE transaction should not bypass least-cost planning. Updated waste, cost and performance data must be submitted for power-system assessment, and any capacity award and power purchase agreement with the Jamaica Public Service Company (JPS) must be secured through the competitive process administered by the Generation Procurement Entity under the oversight of the Office of Utilities Regulation (OUR). If broader waste-management benefits are used to justify public support, those benefits and costs should be appraised transparently rather than embedded opaquely in the electricity tariff.

Financial close also requires closure of Jamaica's core solid-waste regulatory gaps. The Auditor General reported that regulations on disposal facilities and public cleansing had remained under development for years (Auditor General's Department, 2022). Updated regulations should set enforceable licensing and operating standards for WtE plants, sanitary landfills and ash monofills; establish waste-flow, weighing, separation and exclusive-delivery rules; and specify inspection, reporting, closure and enforcement powers. The institutional settlement must also identify a single contracting authority and clarify NSWMA's regulatory, contract-monitoring and enforcement functions where service delivery is concessioned. These measures are conditions of bankability because lenders cannot rely on contractual promises where facility standards, waste control and public accountability remain legally uncertain.

Environmental approval by NEPA is a genuine decision gate. A full environmental-impact assessment must examine site alternatives, airshed and health effects, truck traffic, climate hazards, ash management and cumulative burdens. Siting is not settled. Haddon in St Ann, a parcel of government-owned land near the Highway 2000 North-South corridor, has been under feasibility assessment for expansion, and neighbouring communities have already raised concerns about smoke and nuisance, so its suitability cannot be presumed in advance of the assessment (Jackson, 2023; Radio Jamaica News, 2023). A weak or highly qualified result should trigger redesign, resizing, relocation or a shift to alternatives rather than an attempt to force the project through. Any permitted plant would require continuous emissions monitoring, public reporting, independent verification and emissions controls benchmarked explicitly against European Union best-available-technique standards for large municipal waste combustors, with any divergence deliberate and publicly justified (European Commission, 2019; NEPA, 2007).

Social licence is equally material to long-term performance. Communities affected by legacy dumps require early access to understandable information, meaningful influence over sitting and traffic decisions, a grievance mechanism with response standards, and public access to operating and emissions data. Transition arrangements are also required for informal waste pickers and others whose livelihoods may be displaced by dump closure and system formalisation. These obligations should be integrated into procurement and contract management.

Institutionally, Jamaica should manage the project through a single critical path. A dedicated inter-agency task force, drawing in the NSWMA, NEPA, the DBJ, the Generation Procurement Entity, the OUR and the affected municipal corporations, should coordinate approvals,

generation licensing, PPP appraisal, procurement, land, grid interconnection, the PPA, the waste-supply agreement and residue responsibilities. The immediate enabling work is to refresh the waste baseline, complete site and logistics studies, define enforceable flow control, cost fiscal exposure and prepare the principal contracts in parallel. Financial close should occur only when the environmental permit, generation licence, land rights, interconnection terms, construction wrap and payment-security package are mutually consistent.

4.3 Sustainable-development and innovation implications

The principal innovation is institutional and systemic. An integrated WtE programme would connect waste data, collection logistics, materials recovery, pollution monitoring, power procurement and long-term PPP management. Building those capabilities could improve municipal service performance and create demand for local engineering, environmental services, digital monitoring, maintenance, logistics and circular-economy enterprises. It could also reduce disruptions and health losses associated with dump fires, recover metals and energy from residual waste, and reduce methane from unmanaged disposal.

Capability building should begin during project preparation. Procurement documents should require operator training, apprenticeships and a progressive localisation plan, developed with Jamaica's Human Employment and Resource Training / National Service Training Agency Trust, University of the West Indies, University of Technology and other relevant technical institutions, so that international technology transfer produces a durable Jamaican workforce in plant operations, maintenance, emissions monitoring, logistics and environmental management.

These outcomes align with the Sustainable Development Goals on energy, decent work, infrastructure, sustainable cities, responsible production and climate action. The alignment is nevertheless conditional. A plant that weakens recycling, transfers unpriced liabilities to government, fails emissions tests or burdens already affected communities would not constitute sustainable innovation. The development case therefore depends on measurable service improvements, a credible residual-waste strategy, transparent fiscal treatment, local capability building and public accountability throughout the concession.

5. Concluding Remarks

Jamaica has a credible case for advancing an integrated WtE option to the next stage of appraisal. A 65 MW moving-grate facility could serve as the anchor of an integrated system combining modern collection and transfer, organics diversion, materials recovery, engineered landfill capacity and energy recovery. The technical model supports a design in the order of 850,000 tonnes per year and approximately 484 gigawatt-hours of net Year-4 electricity output, subject to feedstock quality and operating performance. Only the biogenic share should be counted as renewable.

The financial findings are equally conditional. Year-4 lender coverage is strong under the assumed tariff, gate fee, throughput and cost structure, but early-year DSCR is tight and the base-case equity return is below the assumed hurdle. Bankability therefore requires a coherent package of indexed revenues, waste-supply certainty, payment security, effective risk allocation and appropriately structured or blended finance. Public support should be given only where a transparent value-for-money and affordability assessment shows that system-wide benefits justify the exposure.

The appropriate next step is a sequenced decision process. This involves establishing the inter-agency task force; refreshing waste and cost data; testing the project against current electricity planning; completing site, logistics and environmental studies; preparing the principal contracts together; and quantifying all direct and contingent fiscal commitments before tender. If the waste baseline, EIA, electricity-system test or affordability assessment does not support the proposed scale, Jamaica should resize, relocate or defer the plant and intensify sanitary-landfill, anaerobic-digestion, recycling and landfill-gas alternatives. Under that structured approach, WtE can be evaluated as a governed investment in sustainable-development capability.

6. References

Ackbarally, N. (2009, July 15). *Environment-Mauritius: Hold your fire*. Global Issues. https://www.globalissues.org/news/2009/07/15/2194

Auditor General's Department. (2022). *Performance audit – Management of solid waste: National Solid Waste Management Authority*. https://auditorgeneral.gov.jm/wp-content/uploads/2022/07/Performance-Audit-Report-NSWMA-July-25-2022-FINAL.pdf

Brunner, P. H., & Morf, L. S. (2025). Waste to energy, indispensable cornerstone for circular economy: A mini-review. *Waste Management & Research, 43*(1), 26–38. https://doi.org/10.1177/0734242X241227376

Development Bank of Jamaica. (2022). *National solid waste characterization study*. https://dbankjm.com/wp-content/uploads/2020/06/2022-06-Waste-characterization-Results-website-v2-1.pdf

Development Bank of Jamaica. (n.d.). *Integrated solid waste management PPP*. https://dbankjm.com/waste-management-reform-programme/

Dijkgraaf, E., & Vollebergh, H. R. J. (2004). Burn or bury? A social cost comparison of final waste disposal methods. *Ecological Economics, 50*(3–4), 233–247. https://doi.org/10.1016/j.ecolecon.2004.03.029

European Commission. (2019). Commission Implementing Decision (EU) 2019/2010 of 12 November 2019 establishing the best available techniques conclusions for waste incineration. *Official Journal of the European Union, L 312*, 55–91. https://eur-lex.europa.eu/eli/dec_impl/2019/2010/oj/eng

Global Infrastructure Hub. (2020). *PPP Risk Allocation Tool 2019 Edition: Water and waste*. https://www.gihub.org/resources/publications/ppp-risk-allocation-tool-2019-edition/

Hawaiian Electric. (n.d.). *H-POWER (Covanta Honolulu Resource Recovery Venture)*. https://www.hawaiianelectric.com/clean-energy-hawaii/our-clean-energy-portfolio/renewable-energy-sources/biomass/h-power

Inter-American Development Bank. (2020). *Support for improvement of solid waste management* (Project No. JA-T1182). https://www.iadb.org/en/project/JA-T1182

Jackson, S. (2023, October 4). Waste-to-energy plant under consideration for St Ann landfill. *The Gleaner*. https://jamaica-gleaner.com/article/business/20231004/waste-energy-plant-under-consideration-st-ann-landfill

Ministry of Science, Energy, Telecommunications and Transport. (2024). *2022 Jamaica Integrated Resource Plan: 2018 IRP review and update*. https://www.mset.gov.jm/wp-content/uploads/2024/11/2022-Jamaica-Integrated-Resource-Plan.pdf

National Environment Agency. (2026, April 14). *Waste-to-energy incineration plants*. https://www.nea.gov.sg/our-services/waste-management/waste-management-infrastructure/semakau-landfill/waste-to-energy-and-incineration-plants

National Environment and Planning Agency. (2007). *Guidelines for conducting environmental impact assessments and public presentations*. https://www.nepa.gov.jm/sites/default/files/2019-12/EIA-Guidelines-and-Public-presentation-2007.pdf

Nordic Council of Ministers. (2024). *Waste incineration in the Nordic countries: A status assessment with regard to emissions and recycling* (TemaNord 2024:524). https://doi.org/10.6027/temanord2024-524

OECD. (2019). *Waste management and the circular economy in selected OECD countries: Evidence from environmental performance reviews*. OECD Publishing. https://doi.org/10.1787/9789264309395-en

Radio Jamaica News. (2023, September 20). *Councillor-caretaker wants relocation of Haddon dump amid spate of fires*. https://radiojamaicanewsonline.com/local/councillor-caretaker-wants-relocation-of-haddon-dump-amid-spate-of-fires

Tait, P. W., Salmona, J., Sandhu, M., Guscott, T., King, J., & Williamson, V. (2025). Economic, environmental, and sociopolitical aspects of waste incineration: A scoping review. *Sustainability, 17*(12), 5528. https://doi.org/10.3390/su17125528

U.S. Environmental Protection Agency. (2026). *Energy recovery from the combustion of municipal solid waste (MSW)*. https://www.epa.gov/smm/energy-recovery-combustion-municipal-solid-waste-msw

United Nations Framework Convention on Climate Change. (2025). *Article 6.2 reference manual for the accounting, reporting and review of cooperative approaches* (Version 3). https://unfccc.int/documents/634354

CHAPTER 4.

Knowledge Mobilization and Social Sustainability

Knowledge Mobilization and Social Sustainability in Health Based on the Case of Diabetes in Mexico

Diana Montserrath Mojica Hernández

Universidad Autónoma Metropolitana, Mexico, dianmmoher@gmail.com

1. Introduction

The concept of sustainability requires us to transform and understand not only economic, social, and environmental systems, but also the relationships these systems maintain with the institutional, technological, and knowledge systems that sustain collective well-being. In this regard, health constitutes a cross-cutting dimension of social sustainability, particularly in Latin America, where structural inequality, institutional fragmentation, weaknesses in public systems, and disconnections among the actors involved in the issue under study limit equitable access to knowledge-based solutions.

In countries such as Mexico, where public health systems are insufficient and fragmented, the search for solutions to chronic degenerative diseases such as diabetes requires the mobilization of diverse scientific, technological, and innovation capabilities. Although health-oriented policies, research programs, and academic initiatives have been promoted, a gap and disconnect persist between knowledge production and the needs of the population. This gap is compounded by weak coordination and articulation among actors and by cognitive, institutional, social, organizational, and geographical distances that hinder or facilitate the dissemination, appropriation, and use of knowledge.

Along these lines, the problem motivating this paper is expressed in the following research question: what structural factors affect the translation of scientific knowledge into effective solutions for addressing complex social problems in health? To answer this question, we examine two bodies of theory: health innovation systems and Research-Based Knowledge Mobilization (MoCBI), using diabetes in Mexico as the reference case.

The objective is to discuss the production, dissemination, demand, and application of scientific and technological knowledge, identify the actors present at these stages, and propose a classification of demand that makes it possible to study its correspondence with the supply of

knowledge. Accordingly, the article presents a conceptual review, the methodological strategy, the results of the categorization, and the next steps toward representation through agent-based simulation.

2. Literature Review

2.1 Health Innovation Systems

From their beginnings, Science, Technology, and Innovation (STI) studies sought to understand how knowledge production, technological development, and innovation contribute to addressing problems that affect society. In the specific case of health, this perspective must be broadened to consider simultaneously the actors, regulatory framework, funding sources, infrastructure, and dynamics of the problem to be addressed.

Consoli and Mina (2009), Hanlin and Andersen (2019), and Natera et al. (2020) have studied health innovation processes, the obstacles to producing and applying knowledge in developing countries, and the links between innovation studies and the health disciplines. While the former focus on the development of products and services, the health disciplines have concentrated on knowledge generation and its translation into practice. Weak articulation between the two limits the application of the knowledge produced.

In this regard, the Health Innovation Systems (HIS) approach overcomes limitations associated with the linearity of processes. Innovation depends not only on producing knowledge, but also on interactions among those who generate, disseminate, demand, and use it to create value. For this reason, HIS performance is conditioned by actors' capacities to coordinate and build linkages, as well as by the institutional, geographical, organizational, technological, and social contexts in which they interact.

2.2 From Knowledge Transfer to Knowledge Mobilization

The literature has defined and used different concepts to explain how generated knowledge is disseminated toward its application. Knowledge transfer emphasizes the unidirectional processes developed between organizations during exchange and the capacities required by recipients to assimilate and appropriate knowledge; translational research seeks to reduce the gaps between the laboratory, research involving human subjects, and clinical practice; knowledge translation considers feedback cycles and the joint participation of knowledge users in its interpretation; and

knowledge mobilization broadens these approaches to include bidirectional flows, specific contexts, the actors involved at each stage, and the relationships between supply and demand.

Table 1. Approaches to Analyzing Knowledge Dissemination and Application

Approach	Focus	Analytical Limitation
Knowledge transfer	Exchange and adoption of knowledge and technology between organizations.	May oversimplify the understanding of feedback processes if represented as a linear transfer.
Translational research	Progression from basic science to clinical research and practice.	Focuses on representing the sequence of stages and the obstacles to applying knowledge in clinical practice.
Knowledge translation	Feedback among research processes, users, involved actors, and application contexts.	Has limitations in integrating decision-makers and institutional support.
Knowledge mobilization	Identifies bidirectional flows among actors across generation, dissemination, demand, and application, as well as the presence of users and beneficiaries.	Makes it possible to specify stages, actors, and conditions for application to specific problems.

Source: author's own elaboration based on Rojas and Natera (2019).

The Social Sciences and Humanities Research Council defines knowledge mobilization as the reciprocal and complementary flow and uptake of knowledge among researchers, knowledge mobilizers, and users, both within and outside academia, with the aim of producing benefits and impacts (SSHRC, 2020).

This definition recognizes that mobilized knowledge may come from different sources: research, formal education, or experience acquired through doing, using, and interacting (Jensen et al., 2007). Consequently, mobilization is not limited to disseminating results; it encompasses processes of communication, appropriation, learning, and use, as well as the contextual conditions that facilitate or hinder these processes.

2.3 Research-Based Knowledge Mobilization

The Research-Based Knowledge Mobilization framework was developed by Rojas and Natera (2019) to understand the processes of knowledge generation, dissemination, demand, and use in relation to complex health problems. Its contribution lies in connecting these stages through bidirectional relationships and recognizing the participation of heterogeneous actors.

According to the literature review, the actors represented in the Health Innovation System include academia, health institutes, and hospitals, which participate in the stages of knowledge

production. Health service providers intervene in its use; the productive sector can transform results into goods and services and identify the system's needs; and policymakers focus on creating and strengthening capabilities, instruments, and support. They are joined by users and beneficiaries, whose position depends on their relationship with the application of knowledge.

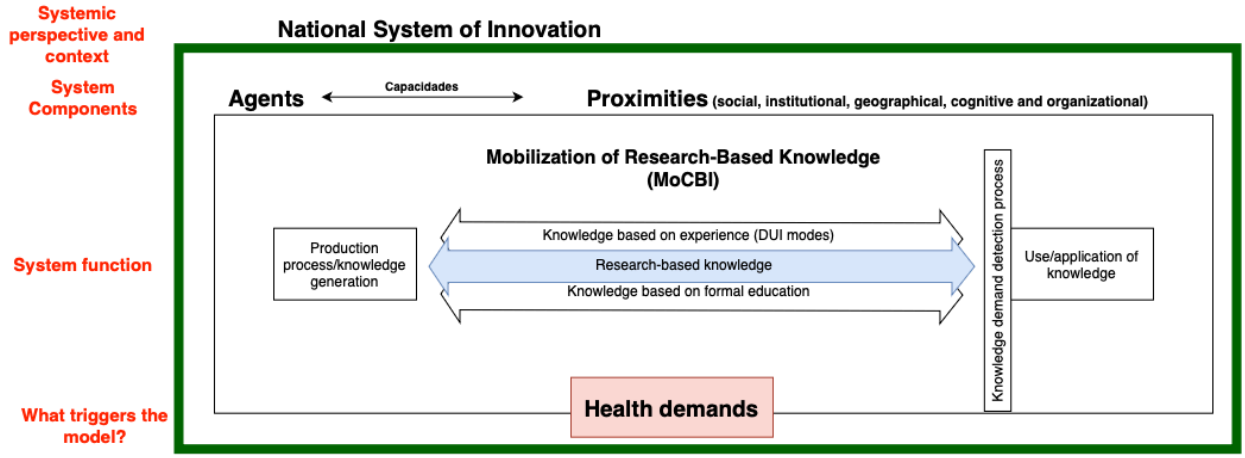


Figure 1. Stages and Actors in Research-Based Knowledge Mobilization
Source: author's own elaboration based on Rojas and Natera (2019).

2.4 Knowledge Demand

Demand is a fundamental stage in the MoCBI process because it guides the production and application of knowledge toward specific needs within the HIS. For an innovation to generate social benefits, continuous communication between producers and users, interaction among basic science, applied research, and implementation, and correspondence between supply and demand are required (Kirat & Lung, 1999; Muscio et al., 2010; Sarewitz & Pielke, 2007).

The literature review shows that Sarewitz and Pielke (2007) propose reconciling scientific supply with expected outcomes. Edler and Georghiou (2007) show that demand can guide innovation and public policy. Arocena and Sutz (2010) warn that weak knowledge demand in developing countries makes it difficult to define priorities and targeted programs. Sarkki et al. (2021) add funding as a link between social needs, research agendas, and scientific supply.

3. Methodology

This paper conducts a conceptual review to propose an analytical framework for studying knowledge mobilization and social sustainability in relation to diabetes in Mexico. The selection

focused on contributions from STI and the social sciences that explain the relationship among knowledge production, dissemination, demand, and use.

The methodology was organized into three stages. First, the concepts of knowledge transfer, translational research, knowledge translation, and knowledge mobilization were analyzed and compared to identify their scope, intersections, and limitations. Second, MoCBI was disaggregated into stages and types of actors according to their nature and relationship with knowledge use. Third, different definitions of demand were reviewed and grouped into four nonexclusive analytical dimensions.

Diabetes serves as the case study because it combines multiple factors and because addressing it requires the use and application of complementary knowledge and capabilities distributed across different institutions. In this regard, the unit of analysis can be understood as the relationship developed among heterogeneous actors as they produce, disseminate, demand, or apply knowledge within the HIS.

This conceptual review provides the basis for subsequently proposing an agent-based simulation model. The model will integrate the proximity framework, the concepts of sustainability, and a typology of demands to represent interactions among actors, explore barriers, and identify possible points of articulation. This article presents the conceptual results that support this representation.

4. Results Analysis

4.1 Diabetes and the Disconnect Between Knowledge Production and Use

Diabetes is a chronic degenerative disease that occurs when blood glucose levels are too high. It has no cure, but people living with the disease can adopt prevention and control measures to keep their health stable.

It can be understood as a complex problem arising from the interaction of multiple biological, social, political, technological, and environmental factors, as well as from insufficient mechanisms, protocols, technologies, and multidisciplinary treatments (Gómez et al., 2011; Hernández-Romieu et al., 2011). Accordingly, the problem cannot be explained or addressed by a single discipline or institution.

In Mexico, diabetes represents a serious public health problem and remains a growing cause of mortality. An analysis of 300 projects funded by CONACYT between 2002 and 2014 showed

that most were oriented toward fundamental or basic science rather than the application of knowledge (Natera et al., 2019). This analysis illustrates the presence of a latent gap between knowledge generation and its application.

Academic knowledge production often responds to incentives focused on political objectives or academic advancement, particularly publications. Moreover, many public universities lack the capabilities required to apply knowledge outside the institution. In this regard, one result is that the problem lies not in an absence of research capabilities, but in insufficient articulation among scientific agendas, demands, health services, policymakers, the business sector, and the users and beneficiaries of knowledge.

4.2 Stages and Actors in the MoCBI Process

The first conceptual result is the delimitation of four related stages: production, dissemination, demand, and use. Demand can modify priorities in research agendas; dissemination can generate linkages, learning, and an evolving understanding of new needs; and application can reveal problems that require knowledge to be produced, appropriated, or adapted.

4.3 Demand Typology

The third result is a proposed typology of knowledge demand comprising four dimensions. The categories are not mutually exclusive: a demand may be public, explicit, internal, and latent, or it may combine different features depending on the actor, scope, and moment at which it is identified.

Table 2. Dimensions for Characterizing Knowledge Demand

Dimension	First Category	Second Category	Criterion for Distinction
Origin	Public	Private	Provision of services, programs, or public policies compared with the needs of companies or industries.
Degree of observability	Explicit	Implicit	A recognized and formulated problem compared with a need that has not yet been precisely defined.
Scale	Internal	External	Requirements within an organization or territory.
Response capacity	Latent	Potential	A need whose fulfillment depends on available capabilities compared with a need for which no solution yet exists.

Source: author's own elaboration based on Arocena and Sutz (2010), Edler and Georghiou (2007), Fabrizio and Thomas (2012), Muscio et al. (2010), and Sarewitz and Pielke (2007).

4.4 Implications for Systemic Analysis and Simulation

Analyzing a complex problem from multiple perspectives allows us to understand that solutions do not follow linear trajectories. They therefore require an understanding of the emerging interactions among the actors that make up the system and of the cognitive, institutional, social, organizational, and geographical distances that condition them.

Agent-based simulation makes it possible to observe how actors relate to one another, the obstacles that restrict knowledge flows, and the points at which supply and demand could be articulated. The model functions as a mixed-method tool for organizing assumptions, constructing scenarios, and identifying milestones in knowledge mobilization.

The main implication is that producing relevant knowledge does not guarantee its application. Social sustainability requires coordination mechanisms, appropriation capabilities, and spaces in which the demands of patients, professionals, health services, and policymakers can engage with the available scientific and technological capabilities.

5. Next Steps

The next stage is to contrast this proposal with empirical evidence from different available information sources: projects funded by CONACYT, case studies, interviews, research studies, published theses, and databases from institutions dedicated to health and diabetes research. This comparison will make it possible to identify the types of demand expressed, who formulate them, and the extent to which they correspond to the defined typologies.

Finally, the model is proposed for constructing scenarios, supporting policy design, and identifying critical points of coordination. Its application to other sectors will require adapting the actors, capabilities, and conditions to the problem under study. The purpose is to analyze how knowledge systems can contribute to more equitable responses to complex problems.

6. References

Alzugaray, S., Mederos, L., & Sutz, J. (2013). Investigación e innovación para la inclusión social: La trama de la teoría y de la política. Isegoría, 48, 25-50. https://doi.org/10.3989/isegoria.2013.048.02

Arocena, R., & Sutz, J. (2010). Weak knowledge demand in the South: Learning divides and innovation policies. Science and Public Policy, 37(8), 571-582. https://doi.org/10.3152/030234210X12767691861137

Consoli, D., & Mina, A. (2009). An evolutionary perspective on health innovation systems, 297-319. https://doi.org/10.1007/s00191-008-0127-3

Edler, J., & Georghiou, L. (2007). Public procurement and innovation: Resurrecting the demand side. Research Policy, 36(7), 949-963. https://doi.org/10.1016/j.respol.2007.03.003

Fabrizio, K. R., & Thomas, L. G. (2012). The impact of local demand on innovation in a global industry. Strategic Management Journal, 33(1), 42-64. https://doi.org/10.1002/smj.942

Gómez, O., Sesma, S., Becerril, V., Knaul, F., Arreola, H., & Frenk, J. (2011). Sistema de salud de México. Salud Pública de México, 53(1), 220-232.

Hanlin, R., & Andersen, M. H. (2019). Putting knowledge flows front and centre in health systems strengthening. Innovation and Development, 1-18.

Hernández-Romieu, A. C., Elnecavé-Olaiz, A., Huerta-Uribe, N., & Reynoso-Noverón, N. (2011). Análisis de una encuesta poblacional para determinar los factores asociados al control de la diabetes mellitus en México. Salud Pública de México, 53(1), 34-39. https://doi.org/10.1590/S0036-36342011000100006

Jensen, M. B., Johnson, B., Lorenz, E., & Lundvall, B. Å. (2007). Forms of knowledge and modes of innovation. Research Policy, 36(5), 680-693. https://doi.org/10.1016/j.respol.2007.01.006

Kirat, T., & Lung, Y. (1999). Innovation and proximity: Territories as loci of collective learning processes. European Urban and Regional Studies, 6(1), 27-38. https://doi.org/10.1177/096977649900600103

Muscio, A., Nardone, G., & Dottore, A. (2010). Understanding demand for innovation in the food industry. Measuring Business Excellence, 14(4), 35-48. https://doi.org/10.1108/13683041011093749

Natera, J. M., Rojas, S., Dutrénit, G., & Vera-Cruz, A. O. (2019). National health problems and useful knowledge: Lessons from public funding of diabetes research in Mexico. Innovation and Development, 9(2), 205-224. https://doi.org/10.1080/2157930X.2019.1567906

Natera, J. M., Rojas, S., Dutrénit, G., & Vera-Cruz, A. (2020). Knowledge dialogues for better health: Complementarities between health innovation studies and health disciplines. Pluto Journals, 36, 30-65.

Rojas, S., & Natera, J. M. (2019). Movilización del conocimiento: Aportes para los estudios sociales de la salud. Revista Ciencias de la Salud, 17(3), 111. https://doi.org/10.12804/revistas.urosario.edu.co/revsalud/a.8369

Sarewitz, D., & Pielke, R. A. (2007). The neglected heart of science policy: Reconciling supply of and demand for science. Environmental Science & Policy, 10(1), 5-16. https://doi.org/10.1016/j.envsci.2006.10.001

Sarkki, S., Rasmus, S., Landauer, M., Lépy, É., & Heikkinen, H. I. (2021). Matching societal knowledge demand, research funding and scientific knowledge supply: Trends and co-creation dynamics around reindeer management in Finland. Polar Geography, 44(2), 90-111. https://doi.org/10.1080/1088937X.2020.1755905

Social Sciences and Humanities Research Council. (2020). Definitions of terms 2016. http://www.sshrc-crsh.gc.ca/funding-financement/programs-programmes/definitions-eng.aspx#km-mc

This special issue of Debates sobre Innovación brings together nine contributions associated with the NACLICS 2026 PhD Academy and Research Conference, held at The University of the West Indies, Cave Hill Campus, Barbados, in June 2026, under the theme: "Modeling Tomorrow: Innovation for Sustainable Development". The academy provided a platform for academic exchange among researchers, doctoral scholars, and practitioners interested in the relationships between innovation, technological capabilities, public policy, and sustainable development. Building upon these discussions, the present collection offers conceptual, empirical, and policy-oriented perspectives on the opportunities and limitations of innovation-led development in small, emerging, and structurally diverse economies.

Puede consultar los números de la Revista en el enlace siguiente:

Casa abierta al tiempo
UNIVERSIDAD AUTÓNOMA METROPOLITANA
DMEGI
2504-0937