Vol. 4, No. 2, 2026
DOI: 10.61975/gjset.v4i2.143

ORIGINAL ARTICLE

From Geothermal Investment to Local Economic Transformation: Developing a Policy-Enabled Conceptual Framework

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Article History

Received
21 August 2026

Accepted
18 October 2026

Available Online
31 October 2026

Keywords

Geothermal investment
Local economic transformation
Linkage quality
Economic embeddedness
Energy-transition governance

Abstract

Geothermal investment can create local economic opportunities, yet these do not necessarily translate into sustained regional transformation. This study develops a Policy-Enabled Conceptual Framework explaining how investment-generated economic linkages may evolve into locally embedded productive capabilities. Using a theory-building design and purposive, theory-driven literature synthesis, the framework integrates geothermal development, extractive-industry linkages, Global Value Chain governance, and regional embeddedness perspectives. It distinguishes five constructs: geothermal investment, local economic linkage mechanisms, linkage quality, economic embeddedness, and local economic transformation. Six linkage mechanisms are identified, while linkage quality is characterized by depth, durability, breadth, and interconnection, distinct from economic embeddedness through local ownership, productive control, and reinvestment. Three governance functions; coordination, capability enabling, and institutionalization; are theorized to influence specific developmental relationships under territorial and project-specific boundary conditions. Seven refutable propositions and an enclave-to-anchor development continuum are proposed. The framework's contribution lies in distinguishing relational linkage quality from territorial economic anchoring and specifying policy-enabled pathways requiring future empirical validation.

Introduction

The global energy transition has increased expectations that renewable energy investment should advance not only decarbonization but also sustained local economic development. Geothermal energy offers particular opportunities through reliable electricity generation, infrastructure provision, and productive heat utilization [1–4]. Such investment may create employment, training, procurement, and enterprise opportunities [5,6]. However, these benefits may remain temporary, unevenly distributed, or weakly connected to regional productive systems [6,7]. The central challenge is therefore to explain how geothermal investment-generated opportunities can develop into enduring local economic capabilities rather than isolated project-related activities.

Extractive-industry linkage theory provides an important foundation for addressing this challenge. Hirschman [8] explains how backward and forward linkages can stimulate productive activities beyond an initiating investment, while Morris et al. [9] demonstrate the industrial development potential of supplier participation and production linkages in resource-based economies. Global Value Chain (GVC) perspectives extend this reasoning by emphasizing governance structures, supplier upgrading, and value capture [7,10]. Regional embeddedness and global production network perspectives further highlight the territorial integration of

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productive activities, institutions, and economic value [11,12]. Together, these approaches suggest that investment and economic participation alone are insufficient measures of development. Yet their contributions require integration to explain how geothermal-related linkages acquire developmental strength and become anchored within host-region economies.

Geothermal development also differs from other resource-based investments in ways that shape local economic relationships. Its geographic dependence on subsurface resources creates place-specific opportunities, while exploration and drilling uncertainty influence investment timing and project continuity [4,13]. Employment and procurement needs vary across exploration, construction, operation, and expansion: construction may generate substantial temporary demand, whereas operations typically require more specialized and recurring services. Long project lifespans may enable continuing supplier relationships, although their developmental benefits are not automatic. Where technically and commercially feasible, direct geothermal use can also support agriculture, processing, tourism, and other productive activities [2–4]. These characteristics make project temporal dynamics, linkage continuity, and local productive capabilities particularly relevant to geothermal-led development.

International studies illustrate both the opportunities and limitations of geothermal investment. Evidence from Kenya's Olkaria area highlights challenges involving employment access, benefit distribution, resettlement, and community representation [14]. Research on the Makiling-Banahaw Geothermal Complex in the Philippines emphasizes stakeholder engagement, institutional cooperation, and trust [15]. Iceland demonstrates the significance of long-term geothermal direct utilization, particularly district heating [16], while research from Aotearoa New Zealand highlights the importance of integrating cultural, environmental, social, and economic considerations [17]. These studies document different dimensions of geothermal development but do not individually establish how project-generated linkages translate into territorially retained productive capabilities.

In Indonesia, comparative research identifies institutional and policy conditions influencing geothermal investment and financing [18], while evidence from Dieng highlights challenges involving community participation and policy advocacy [19]. National assessments further document geothermal potential and development conditions [4,13]. Sokoria in Ende Regency, East Nusa Tenggara, provides a relevant illustrative context. Official documentation identifies a staged development plan of up to 30 MW [20] and reports commercial operation of Sokoria Unit 2 in July 2023, adding 5 MW of installed capacity [21]. These milestones demonstrate geothermal investment activity but do not establish the quality of local supplier relationships, productive ownership, reinvestment, or structural economic outcomes. Sokoria is therefore used as a secondary-source illustration rather than an empirically validated case study.

Three interrelated research gaps emerge. First, existing geothermal socioeconomic assessments and extractive-industry approaches do not consistently distinguish the formation of economic linkages from their developmental quality. Employment or procurement participation may occur without meaningful capability upgrading, broad participation, or relationship continuity. Second, Linkage quality and economic embeddedness require clearer differentiation. The former concerns relational characteristics: depth, durability, breadth, and interconnection; whereas the latter concerns territorial productive anchoring through local ownership and control, reinvestment, and retained decision-making. Technically advanced or durable supplier relationships can therefore coexist with limited local economic control. Third, existing perspectives do not sufficiently specify how differentiated governance functions and geothermal project phases condition the progression from linkage opportunities to local economic transformation. To address these gaps, this study develops a policy-enabled conceptual framework connecting five constructs: geothermal investment, local economic linkage mechanisms, linkage quality, economic embeddedness, and local economic transformation. Six mechanisms are distinguished: employment and skills development, local

procurement, MSME participation and upgrading, productive and direct geothermal use, infrastructure and service linkages, and local value-chain and market integration. Governance and policy alignment operate through coordination, capability enabling, and institutionalization [10,22], subject to territorial capability, infrastructure and connectivity, institutional capacity, and project temporal dynamics. The proposed relationships allow for phase-dependent variation, possible direct pathways, and feedback rather than assuming an inevitable linear progression.

The contribution of this study is integrative rather than a claim to have originated economic linkage or embeddedness theory. By combining extractive-industry linkage theory, global value chain perspectives, regional embeddedness, and energy-transition governance, the study differentiates linkage formation, relational quality, territorial anchoring, and structural transformation within the geothermal development context. Accordingly, the main objective of this study is to develop a policy-enabled conceptual framework that explains how geothermal investment may contribute to sustained local economic transformation through differentiated economic linkage mechanisms, linkage quality, and economic embeddedness, while specifying the enabling roles of governance and contextual boundary conditions. The framework further develops seven theoretically derived, refutable propositions to guide future empirical research.

Materials and Methods

Research Design and Conceptual Approach

This study employs a theory-building conceptual research design to develop a Policy-Enabled Conceptual Framework explaining how geothermal investment may contribute to sustained local economic transformation. Following Jaakkola [23], the study adopts a conceptual model-development approach supported by theory synthesis. This design enables the differentiation of constructs, specification of theoretical relationships, and identification of governance and contextual conditions without empirical hypothesis testing. The framework addresses the explanatory gap between geothermal investment-generated opportunities and sustained regional development. It draws on four complementary theoretical domains: geothermal development, extractive-industry and GVC linkages, energy-transition governance, and regional embeddedness. These perspectives inform the distinction between economic linkage formation, relational developmental characteristics, territorial economic anchoring, and structural transformation. No primary data collection, experimental procedures, or quantitative causal estimation was undertaken.

Literature Selection and Conceptual Evidence Base

A purposive, theory-driven literature synthesis was employed rather than an exhaustive systematic literature review. Scholarly publications and selected institutional reports were considered for their relevance to four analytical domains: (i) geothermal investment characteristics and socioeconomic opportunities; (ii) extractive-industry linkages, enterprise participation, and productive upgrading; (iii) governance, institutional coordination, and policy alignment; and (iv) regional embeddedness, territorial value retention, and local economic transformation. Source selection was guided by theoretical relevance, explanatory complementarity, and the capacity to clarify constructs or proposed relationships. Foundational studies on economic linkages, GVC governance, and regional production networks provide theoretical support [7–12]. Geothermal-specific research and institutional assessments inform sector characteristics, development uncertainties, productive applications, and socioeconomic opportunities [1–6,13]. Governance literature informs the institutional functions and policy-enabling conditions [10,22]. Sources were differentiated by analytical function: theoretical foundations, sectoral illustrations, policy and institutional context, or methodological guidance.

The available literature records do not support a complete reconstruction of database searches, screening decisions, or study-level inclusion counts. Accordingly, the study makes no claim of exhaustive systematic screening, quantitative evidence aggregation, or a reproducible systematic-review sample. Although Naeem et al. [24] discuss formal thematic analysis, this

research did not conduct systematic thematic coding, intercoder reliability assessment, or empirical qualitative data analysis. Supplementary Table S1 provides traceability between the selected references, their analytical roles, and their contributions to framework development; it is not a systematic evidence inventory.

Mechanism Identification and Construct Differentiation

Mechanisms were differentiated according to three conceptual criteria: (i) an identifiable channel connecting geothermal investment with host-region economic actors or activities; (ii) a distinguishable primary economic function, despite potential overlap; and (iii) a plausible relationship with productive participation, capability development, or regional value creation. Applying these criteria, six linkage mechanisms were specified: employment and skills development; local procurement; MSME participation and upgrading; productive and direct geothermal use; infrastructure and service linkages; and local value-chain and market integration. The categories distinguish workforce participation, purchasing relationships, enterprise capability development, productive resource utilization, infrastructure-related opportunities, and broader market integration. They are analytically distinguishable but not mutually exclusive. For example, a supplier may simultaneously participate in procurement, undergo technical upgrading, and access wider markets.

Community development expenditure, public transfers, and geothermal production bonuses were not classified as independent productive linkage mechanisms because they primarily operate through redistributive or enabling channels unless linked to identifiable productive activities. Their potential developmental influence is instead considered within governance and institutional arrangements. Construct differentiation further separates linkage mechanisms from their relational characteristics and territorial consequences. Linkage quality comprises four proposed dimensions: depth (capability upgrading and higher-value participation), durability (continuity of economic relationships), breadth (distribution of participation), and interconnection (functional complementarity across linkage mechanisms). These dimensions exclude local ownership, reinvestment, and productive control, which characterize economic embeddedness. Local economic transformation is separately defined through broader structural changes in regional productive activity and diversification.

Supplementary Table S2 documents the theoretical rationale, conceptual boundaries, and potential relational manifestations of the four linkage quality dimensions. These specifications are theory-derived rather than outputs of formal coding and require future empirical validation.

Cross-Theory Integration and Framework Development

The framework was developed through abductive cross-theory integration, combining complementary explanations to address why investment-generated economic opportunities do not necessarily produce sustained territorial transformation. Extractive-industry linkage theory and GVC perspectives explain economic participation, supplier relationships, upgrading, and value capture [7–10]. Regional embeddedness and global production network perspectives explain territorial anchoring, locally retained productive control, and economic value retention [11,12]. Energy-transition governance contributes an institutional explanation of how coordination, capability enabling, and institutionalization may influence these processes [10,22].

The integration assigns distinct explanatory roles to these perspectives rather than treating them as interchangeable. It differentiates five constructs: geothermal investment as the initiating condition; local economic linkage mechanisms as transmission channels; linkage quality as relational developmental characteristics; economic embeddedness as territorial productive anchoring; and local economic transformation as broader structural outcomes. Governance and policy alignment are specified as cross-cutting enabling conditions rather than a sequential mediator, while territorial capability, infrastructure and connectivity, institutional capacity, and project temporal dynamics are treated as boundary conditions.

The framework proposes an analytically ordered developmental pathway without assuming deterministic or irreversible causality. Phase-dependent variations, potential direct effects, and feedback relationships remain theoretical possibilities requiring empirical examination. Figure 1 summarizes the six-step conceptual development logic: explanatory problem specification, theoretical evidence organization, mechanism and construct differentiation, abductive cross-theory integration, policy-enabled framework specification, and conceptual outputs. The figure represents the analytical reasoning process, not a documented systematic search, screening, or coding workflow.

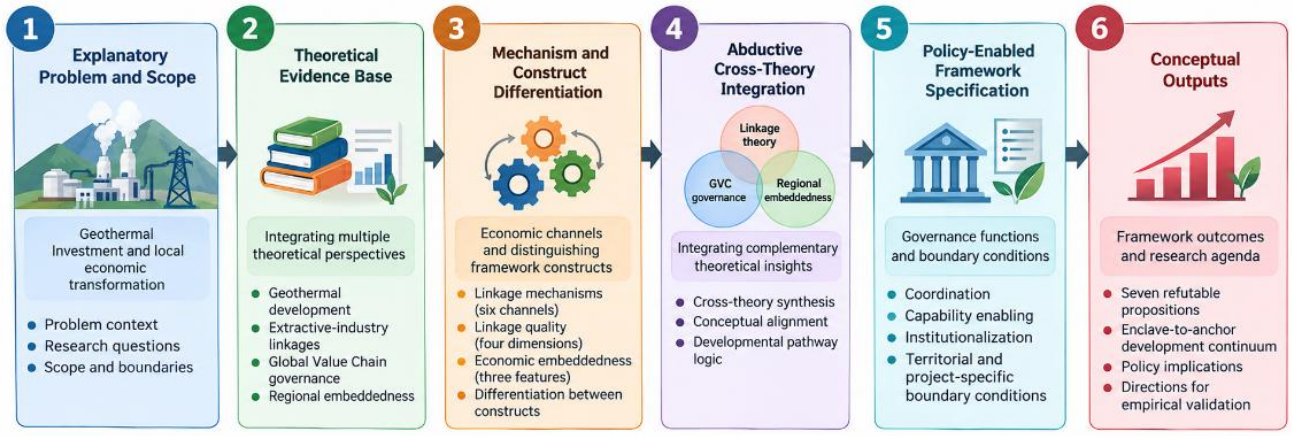


Figure 1. Development of the policy-enabled conceptual framework. Note: adapted from the conceptual research approach of Jaakkola [23].

Results and Discussion

Conceptual Framework and Theoretical Contribution

The proposed Policy-Enabled Conceptual Framework explains how geothermal investment may contribute to sustained local economic transformation through a sequence of analytically differentiated processes. Rather than treating investment, economic participation, and regional development as equivalent outcomes, it distinguishes five constructs: geothermal investment, local economic linkage mechanisms, linkage quality, economic embeddedness, and local economic transformation. Their relationships represent a proposed developmental pathway, not an empirically established causal sequence.

Geothermal investment constitutes the initiating condition, encompassing capital, technology, expertise, and resources deployed across project phases. Local economic linkage mechanisms capture the channels connecting investment with host-region workers, enterprises, productive resources, infrastructure, and markets. Linkage quality evaluates the developmental characteristics of these relationships through depth, durability, breadth, and interconnection. Economic embeddedness concerns their territorial anchoring through local ownership and productive control, reinvestment, and retained decision-making. Local economic transformation denotes broader structural outcomes, including diversification, productivity improvement, and expanded regional productive capabilities.

These distinctions clarify why investment expenditure or local procurement cannot independently demonstrate economic transformation. Participation may generate economic activity without improving productive capabilities; technically sophisticated supplier relationships may persist without increasing locally retained ownership or value; and greater local control may not immediately produce measurable structural diversification. The framework therefore separates the formation, quality, territorial retention, and wider developmental consequences of economic relationships.

Table 1 summarizes the conceptual roles, distinguishing characteristics, theoretical foundations, and proposition-level relationships of the framework components. Governance and policy alignment are identified as cross-cutting enabling conditions, while territorial and project-specific boundary conditions influence the effectiveness of the proposed relationships. Compared with existing geothermal socioeconomic assessments, which primarily identify categories of employment, infrastructure, community benefits, and development opportunities [1,6], the proposed framework distinguishes the formation of economic linkages from their relational quality, territorial anchoring, and broader structural consequences. While extractive-industry linkage theory emphasizes the generation of productive relationships [8,9], Global Value Chain perspectives highlight upgrading and value capture [7–10], and regional embeddedness theory explains territorial integration [11,12], these perspectives address different parts of the developmental process. The present framework integrates their complementary insights while specifying geothermal project-phase dynamics, differentiated governance functions, and contextual moderators. Its novelty lies in this theoretical integration and the formulation of refutable relationships rather than in claiming entirely new underlying concepts.

Table 1. Construct-to-proposition traceability.

Framework Component	Conceptual Definition and Analytical Role	Distinguishing Feature	Theoretical Foundation	Proposition
Geothermal Investment	Capital, technology, expertise, and resources committed across geothermal project phases; initiating condition	Investment inputs, not development outcomes	Geothermal development [1,4,13]	P1
Local Economic Linkage Mechanisms	Economic interaction channels connecting geothermal projects with host-region actors and activities	Formation and type of economic relationships	Linkage theory; GVC [7–9]	P1–P2
Linkage Quality	Relational developmental characteristics defined by depth, durability, breadth, and interconnection	How linkages function and develop	GVC; linkage theory [7,9,10]	P2–P3
Economic Embeddedness	Territorial anchoring through local ownership/control, reinvestment, and locally retained productive decision-making	Where productive control and economic value are anchored	Embeddedness; GPN [11,12]	P3–P4, P7
Local Economic Transformation	Sustained structural change in productive activities, diversification, and regional capabilities	Regional structural outcomes	Regional development [6,9,12]	P4
Governance and Policy Alignment	Cross-cutting enabling architecture with coordination, capability enabling, and institutionalization	Institutional influence on selected relationships	ETG; policy-enabled upgrading [10,22]	P5
Boundary Conditions	Territorial and project-specific factors influencing the strength of proposed relationships	Contextual conditioning, not another developmental stage	Cross-theory synthesis [13,22,25]	P6
Enclave–Anchor Development Trajectory	Ideal-type continuum of territorial economic integration and value retention	Alternative developmental configurations	Linkage theory; embeddedness [9,11,12]	P7

Its contribution is therefore integrative, rather than the introduction of economic linkages or embeddedness as entirely new concepts. Compared with broader geothermal sustainability assessment approaches [6] and socioeconomic benefit categories identified by ESMAP [1], the framework focuses on the mechanisms connecting project-generated opportunities to locally retained productive capabilities. It further distinguishes relational linkage quality from territorial economic embeddedness and incorporates geothermal project phases, targeted governance functions, and contextual conditions into refutable theoretical relationships. The resulting framework provides a basis for examining why similar geothermal investments may generate different regional development trajectories. Its constructs and propositions remain theory-derived and require comparative and longitudinal empirical validation.

Local Economic Linkage Mechanisms

The framework identifies six economic linkage mechanisms through which geothermal investment may interact with host-region productive systems: (i) employment and skills development, (ii) local procurement, (iii) MSME participation and upgrading, (iv) productive and direct geothermal use, (v) infrastructure and service linkages, and (vi) local value-chain and market integration. These mechanisms build on geothermal socioeconomic development research [1,5,6], extractive-industry linkage theory [8,9], and GVC upgrading perspectives [7–10].

The mechanisms are distinguished by their primary economic functions rather than treated as mutually exclusive activities. Employment and skills development concerns workforce participation and capability formation, whereas local procurement concerns purchasing relationships between projects and suppliers. MSME participation and upgrading focus on enterprise inclusion and improvements in technical, managerial, and productive capabilities. Productive and direct geothermal use involves feasible non-electricity applications of geothermal resources. Infrastructure and service linkages concern access to facilities and services supporting productive activity, while value-chain and market integration captures relationships extending beyond isolated project transactions. These distinctions are particularly important for procurement, enterprise upgrading, and market integration. A supplier may receive a geothermal procurement contract without developing new capabilities. Subsequent technical upgrading represents a different mechanism, while diversification into additional buyers or production networks reflects wider market integration. The mechanisms may therefore reinforce one another without being conceptually interchangeable.

The composition and developmental potential of these linkages also vary across geothermal project phases. Exploration and drilling often require specialized expertise; construction may create intensive but temporary employment and procurement opportunities; and operations may support recurring technical-service relationships. Productive geothermal applications can provide additional opportunities where resource accessibility, technical feasibility, institutional arrangements, and market conditions permit [2–4].

Importantly, linkage formation does not establish developmental quality or territorial retention. Temporary procurement may increase local expenditure without supplier upgrading, while infrastructure provision may improve accessibility without ensuring productive use by local enterprises. Conversely, complementary investments in workforce skills, supplier capabilities, infrastructure, and market access may strengthen the developmental potential of economic linkages. These outcomes remain conditional and are examined through linkage quality and economic embeddedness in the following section. Table 2 presents the conceptual boundaries, primary economic functions, and potential developmental contributions of the six mechanisms.

Table 2. Local economic linkage mechanisms, analytical boundaries, and developmental functions.

Linkage Mechanism	Primary Function and Analytical Boundary	Potential Developmental Contribution
1. Employment and skills development	Worker recruitment, training, certification, and occupational learning; distinguishes workforce capabilities from enterprise upgrading	Enhanced employability, skills transfer, technical competence
2. Local procurement	Purchasing of goods and services from locally operating suppliers; measures transactions, not capability upgrading or ownership	Local business opportunities and retention of procurement expenditure
3. MSME participation and upgrading	Entry of MSMEs into project-related activities and measurable improvement in technical, managerial, or production capabilities	Productivity improvement, supplier upgrading, higher-value participation
4. Productive and direct geothermal use	Technically and economically feasible use of geothermal heat/resources for non-electricity activities	New productive applications, resource-based enterprise opportunities, diversification potential
5. Infrastructure and service linkages	Access to roads, utilities, connectivity, logistics, and services generated or strengthened by project development	Lower transaction costs, improved accessibility, economic opportunities
6. Local value-chain and market integration	Participation in broader production networks, buyer relationships, downstream activities, and markets beyond isolated project contracts	Market expansion, production-network integration, potential local value capture

Note: Mechanisms are analytically differentiated by their principal economic functions and may overlap in practice. A local enterprise can participate simultaneously in procurement, upgrading, and value-chain integration. Potential contributions are theoretical, not observed outcomes of the Sokoria project.

Linkage Quality and Economic Embeddedness

A central contribution of the framework is the analytical separation of linkage quality and economic embeddedness. Although theoretically related, these constructs capture different developmental characteristics. Linkage quality concerns how economic relationships develop and function, whereas economic embeddedness concerns whether productive activities and associated economic value become territorially anchored. Their distinction is essential because strong economic participation does not necessarily generate local productive control or retained economic benefits.

Quality comprises four theory-derived dimensions: depth, durability, breadth, and interconnection [7–10]. Depth captures capability upgrading and movement toward higher-value participation. Durability concerns continuity of economic relationships across relevant observation periods or project phases. Breadth reflects the distribution of participation among eligible workers, enterprises, and economic activities. Interconnection captures functional complementarities among distinct linkage mechanisms, such as connections between workforce development, supplier upgrading, infrastructure, and market access. These dimensions characterize economic relationships rather than the ownership or territorial retention of their benefits. In particular, durability is restricted to relationship continuity, while interconnection concerns cross-mechanism complementarity. Neither constitutes evidence of local ownership, reinvestment, or productive decision-making. Supplementary Table S2 documents their theoretical rationale and conceptual boundaries.

Economic embeddedness is defined through the territorial organization and retention of productive activities, drawing on regional embeddedness and global production network perspectives [11,12]. Its distinguishing attributes are local beneficial ownership and effective productive control, locally retained and reinvested economic returns, and the location of strategic productive decision-making. These attributes concern who controls productive resources and where economic value is retained, rather than the quality or continuity of project-related transactions. Economic embeddedness is also distinct from Local Economic Transformation. The former concerns territorial productive anchoring, whereas the latter

concerns broader regional outcomes such as diversification, productivity growth, and changes in sectoral economic structure.

Contrasting Conceptual Configurations

The distinction can be illustrated through two hypothetical cases. First, a geothermal project may maintain long-term contracts with technically advanced suppliers, provide extensive workforce training, and connect multiple productive activities. These relationships indicate relatively high Linkage quality. However, economic embeddedness may remain low where suppliers are externally owned, strategic decisions are made outside the host region, and earnings are predominantly transferred elsewhere. Conversely, locally owned enterprises may retain earnings and exercise productive decision-making authority, indicating relatively high economic embeddedness, while maintaining narrow, technologically simple, or weakly interconnected relationships with the geothermal project. This configuration illustrates that territorial anchoring can coexist with relatively low linkage quality. These contrasting cases establish that linkage quality and economic embeddedness are neither identical nor necessarily proportional. Their relationship is conditional, not definitional.

Implications for Measurement and Proposition P3

Empirical assessment must use non-overlapping indicators. Linkage quality may be examined through verified capability upgrading, contract continuity, participation distribution, and cross-mechanism collaboration. Economic embeddedness instead requires indicators of locally controlled productive assets, territorial reinvestment, and retained strategic decision-making. Regional structural outcomes must be measured separately. Accordingly, Proposition P3 predicts that stronger Linkage quality may increase subsequent economic embeddedness under favorable institutional and territorial conditions. The relationship would be challenged by evidence of consistently strong linkages without corresponding increases in local control or reinvestment. Establishing this distinction requires construct validation and longitudinal analysis rather than assuming territorial embeddedness follows automatically from relational quality.

Governance, Policy Alignment, and Boundary Conditions

Governance and policy alignment are conceptualized as cross-cutting enabling conditions influencing geothermal-related economic linkages rather than as a separate developmental stage or statistically tested mediator. Drawing on governance, policy-enabled upgrading, and regional production-network perspectives [10,12,22], the framework distinguishes three functions: coordination, capability enabling, and institutionalization, each targeting a different developmental relationship.

Coordination (P5a) aligns developers, government institutions, enterprises, training providers, and communities to identify accessible economic opportunities. It primarily strengthens the relationship between geothermal investment and local economic linkage mechanisms through procurement alignment, workforce matching, and coordinated infrastructure planning. It may also improve interconnection among linkage mechanisms, but does not independently guarantee supplier upgrading or local value retention.

Capability enabling (P5b) strengthens workers' and enterprises' capacity to participate in higher-value activities through training, supplier certification, technical assistance, appropriate finance, and enterprise upgrading. It primarily targets the transition from linkage participation to higher linkage quality, particularly depth and breadth. These interventions are especially relevant where geothermal technical requirements exceed existing local capabilities [7,9,10].

Institutionalization (P5c) embeds development objectives into continuing policies, contractual arrangements, organizational responsibilities, and monitoring systems. It may improve the

durability of economic relationships and facilitate the transition from linkage quality to economic embeddedness by enabling local ownership opportunities, productive control, and reinvestment. However, institutional continuity does not guarantee territorial anchoring when strategic decisions or productive assets remain externally controlled.

These governance functions are complementary but analytically distinct: coordination connects opportunities, capability enabling strengthens participation, and institutionalization seeks to sustain and anchor productive relationships. Their effectiveness depends on four contextual boundary conditions, which moderate specific relationships rather than constitute additional causal stages.

Territorial capability (P6a) refers to existing workforce skills, enterprise competencies, productive assets, and absorptive capacity. It conditions whether linkage participation leads to meaningful upgrading and higher linkage quality. Firms with stronger capabilities may respond more effectively to technical opportunities, whereas weak capabilities may constrain upgrading despite increased procurement expenditure [9,10,25].

Infrastructure and connectivity (P6b) encompass transport, utilities, communications, logistics, and market access. They condition linkage formation and interconnection by determining whether local enterprises can reach project demand, coordinate production, and participate in wider markets. Improved connectivity may therefore increase economic opportunities without necessarily producing local ownership or reinvestment.

Institutional capacity (P6c) concerns the administrative, technical, financial, and organizational ability of institutions to implement development interventions. Unlike governance functions, which describe institutional actions, institutional capacity represents the conditions under which those actions can be implemented effectively. Weak implementation resources or monitoring authority may limit otherwise well-designed coordination, capability-support, and institutionalization policies [22].

Project temporal dynamics (P6d) capture differences in investment, employment, procurement, and technical requirements across exploration, construction, operation, and expansion. Exploration and drilling often require specialized external expertise; construction may produce intensive but temporary contracting opportunities; and operation may support recurring, specialized services [2,4,13]. Consequently, project phases shape linkage composition and continuity. Construction linkages may be less durable than operational relationships unless supported by transferable skills, continuing supplier opportunities, or institutional arrangements. Conversely, recurring operational contracts do not automatically generate deeper local capabilities.

The framework also allows possible direct pathways and feedback effects. Infrastructure and productive geothermal applications may contribute directly to regional diversification where technical, market, and institutional conditions permit. Such pathways complement rather than invalidate the principal sequence. Similarly, locally retained capabilities may improve future supplier readiness, expand market access, and support participation in subsequent geothermal investment [9,12]. These potential relationships require empirical testing and are not treated as established causal effects. Overall, P5 specifies differentiated governance effects, while P6 identifies the contextual conditions shaping those effects and the underlying developmental relationships. Their combination explains why similar geothermal investments may generate different outcomes across host regions and project phases.

Development Trajectories and Theoretical Propositions

The policy-enabled conceptual framework links geothermal investment, local economic linkage mechanisms, linkage quality, economic embeddedness, and local economic transformation

through a proposed developmental pathway. These constructs represent analytically distinct stages of explanation rather than a deterministic causal sequence. Governance influences selected relationships, while contextual boundary conditions shape their effectiveness. Direct pathways and feedback effects are included as exploratory relationships requiring future empirical examination.

Figure 2 distinguishes the principal developmental pathway from targeted governance effects and contextual moderators. Coordination, capability enabling, and institutionalization influence the relationships specified in P5, while territorial capability, infrastructure and connectivity, institutional capacity, and project temporal dynamics condition the relationships addressed in P6. The framework therefore allows economic development trajectories to differ across geothermal projects despite comparable investment levels.

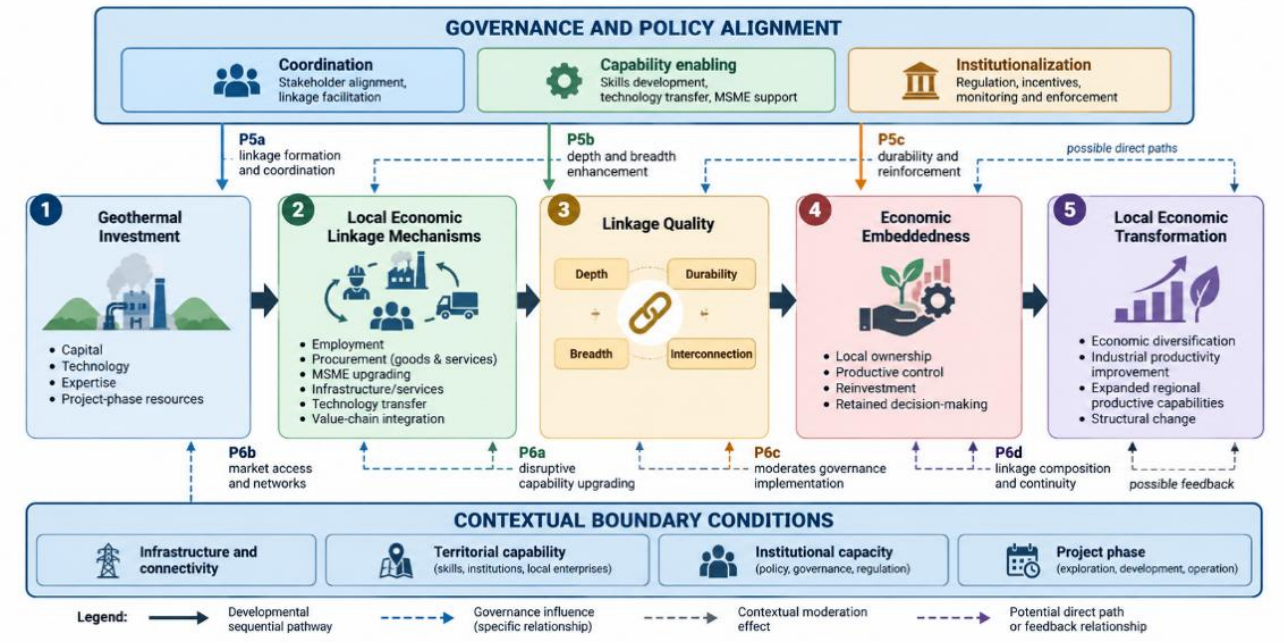


Figure 2. Policy-enabled conceptual framework for geothermal-led local economic transformation. Note: Author-developed conceptual synthesis based on extractive-industry linkage theory [8,9], global value chain perspectives [7,10,22], regional embeddedness and global production network theory [11,12].

Enclave-Oriented and Anchor-Economy Development Trajectories

Drawing on extractive-industry linkages and regional embeddedness perspectives [8,9,11,12], the framework distinguishes two ideal-type trajectories. An enclave-oriented trajectory occurs when project-related economic activities depend heavily on externally controlled suppliers, specialized expertise, and expenditure, with limited local productive control or reinvestment. Employment and procurement may increase without establishing durable territorial productive capabilities.

An anchor-economy trajectory, by contrast, involves stronger local enterprise capabilities, productive relationships extending beyond project demand, locally retained decision-making, and reinvestment into additional economic activities. Geothermal investment may thereby support wider regional productive development rather than remain an isolated energy project. These trajectories form a continuum rather than mutually exclusive categories: enclave-like and anchor-like characteristics may coexist, and movement toward greater territorial anchoring is neither automatic nor irreversible.

Sokoria as an Illustrative Context

Sokoria in Ende Regency, Indonesia, illustrates the relevance and evidentiary limits of the framework. Official energy-sector documentation records a staged geothermal development plan and commercial operation of Sokoria Unit 2 in July 2023 [20,21]. These milestones confirm project development but do not establish the quality of local supplier relationships, ownership arrangements, productive reinvestment, or regional diversification. Applying the framework would require evidence on supplier upgrading, relationship continuity, local productive control, and retained economic benefits. Sokoria therefore cannot be classified as enclave-oriented or anchor-economy based on the available secondary sources alone.

Development of Theoretical Propositions

Table 3 shows the seven directional and potentially refutable propositions to translate the framework into researchable relationships. P1 and P2 distinguish economic linkage formation from capability upgrading; P3 examines whether higher linkage quality predicts subsequent economic embeddedness; and P4 examines whether territorial anchoring contributes to structural diversification. P5 specifies differentiated governance effects, P6 identifies relationship-specific contextual moderators, and P7 addresses longer-term developmental trajectories. P1 draws on extractive-industry linkage theory [8,9], while P2 builds on GVC upgrading and policy-enabled capability development [7,10]. P3 integrates relational development with territorial embeddedness perspectives [11,12], without defining ownership and reinvestment as dimensions of linkage quality. P4 extends regional production-network reasoning to subsequent productive diversification [9,12]. P5 differentiates governance functions [10,22], whereas P6 integrates geothermal project uncertainty and regional absorptive-capacity conditions [13,22,25]. P7 combines resource-linkage and embeddedness explanations to distinguish territorial anchoring from investment magnitude [8,9,11,12].

Table 3. Theory-derived propositions and refutable relationships in the policy-enabled conceptual framework.

Proposition	Directional and Refutable Relationship	Refs.
P1: Linkage formation	Greater alignment between geothermal project demand and accessible local opportunities predicts higher local employment and supplier participation than investment expansion without such alignment, conditional on project phase.	[8,9]
P2: Capability upgrading	Sustained capability support predicts greater subsequent workforce and supplier upgrading than transactional project participation alone.	[7,10]
P3: Territorial anchoring	Higher linkage quality predicts greater subsequent local productive control and reinvestment where ownership opportunities and enabling institutions exist, compared with similarly strong linkages lacking these conditions.	[11,12]
P4: Structural transformation	Greater locally controlled productive activity and reinvestment predict stronger subsequent non-geothermal diversification than comparable contexts with predominantly externally retained value.	[9,12]
P5: Governance differentiation	Coordination strengthens linkage formation/interconnection (P5a); capability enabling improves upgrading/breadth (P5b); institutionalization supports durability and the likelihood of territorial anchoring (P5c).	[10,22]
P6: Contextual moderation	Territorial capability strengthens upgrading responses (P6a); connectivity supports linkage formation/interconnection (P6b); institutional capacity strengthens governance implementation (P6c); project phases alter linkage composition and continuity (P6d).	[13,22,25]
P7: Development trajectories	Higher linkage quality combined with increasing local control and reinvestment predicts stronger progression toward anchor-economy characteristics than high investment with persistently weak embeddedness.	[8,9,11,12]

The proposed relationships should be interpreted as theoretical expectations, not validated findings. Empirical assessment requires independent measurement of constructs, appropriate comparison groups, and longitudinal observation to distinguish developmental sequences from simultaneous or externally driven economic changes. Particular priority should be given to P3 because the empirical separability of linkage quality and economic embeddedness is central to the framework's theoretical contribution.

Policy Implications and Development Monitoring

The Policy-Enabled Conceptual Framework suggests that geothermal development policies should move beyond investment expenditure, installed electricity capacity, and short-term employment indicators to examine the formation, quality, and territorial retention of productive economic relationships. Its policy relevance lies in differentiating three governance functions, coordination, capability enabling, and institutionalization, and linking them to specific developmental processes, as shown in Table 4. These relationships remain theoretical and do not establish that particular policy instruments have produced local economic transformation [1,6,8–10].

Table 4. Governance functions, policy instruments, framework relationships, and development-monitoring indicators.

Governance Function	Proposed Instruments and Responses	Targeted Relationship	Selected Monitoring Indicators
Coordination (P5a)	Joint procurement planning, host-region supplier mapping, workforce matching, and institutional coordination. National domestic-content policy context: Permen ESDM 11/2024 and Kepmen ESDM 191/2024 [26,27]	Investment → Linkage Mechanisms; interconnection	Host-region supplier participation (%); local procurement (IDR/year); documented partnerships (number)
Capability enabling (P5b)	Technical training, certification, MSME upgrading, appropriate financing, and feasible productive geothermal-use initiatives.	Linkage Mechanisms → Linkage Quality (depth, breadth)	Verified supplier upgrading (%); certified workers (%); feasible productive-use initiatives (number)
Institutionalization (P5c)	Multi-year supplier partnerships, transparent monitoring, regional planning, and accountable consideration of production-bonus revenues under PP 28/2016 and Permen ESDM 23/2017 [28,29]	Linkage durability; potential transition from Linkage Quality → Economic Embeddedness	Contract renewal (%); programme continuity (years); verified bonus revenue (IDR/year); productive-development expenditure (IDR/year)

Note: Proposed interventions are framework-derived applications rather than legally mandated outcomes. TKDN requirements should not be equated with host-region procurement. Geothermal production bonuses do not automatically establish enterprise upgrading, local reinvestment, or economic embeddedness. Relevant instruments must be interpreted according to their applicable legal scope, and all developmental effects require empirical assessment.

Differentiated Governance Functions and Policy Instruments

Coordination primarily targets the relationship between geothermal investment and local economic linkage mechanisms (P5a). Joint procurement planning, supplier mapping, workforce-demand forecasting, and coordination among developers, regional governments, and training institutions may improve access to project-related opportunities. In Indonesia, Minister of Energy and Mineral Resources Regulation No. 11/2024 and Ministerial Decree No. 191.K/EK.01/MEM.E/2024 provide the national regulatory context for domestic-product requirements in electricity infrastructure development [26,27]. However, compliance with

domestic-content requirements does not necessarily demonstrate procurement from enterprises located in geothermal host regions. Host-region participation therefore requires separate geographical definitions, supplier records, and monitoring arrangements.

Capability enabling targets the transition from economic participation to higher linkage quality (P5b). Vocational training, certification, technical assistance, enterprise upgrading, and access to suitable financing may strengthen supplier capabilities and broaden participation. These interventions should be assessed through demonstrated improvements in technical competence, production standards, and higher-value economic activities rather than training expenditure or participation counts alone. [7,9,10]. Productive geothermal applications may also create enterprise opportunities where technical feasibility, resource access, and market conditions permit.

Institutionalization supports relationship continuity and the conditions for territorial economic anchoring (P5c). Multi-year supplier-development arrangements, continuing skills partnerships, regional planning, and transparent monitoring may strengthen linkage durability. Indonesia's geothermal production-bonus framework, established through Government Regulation No. 28/2016 and Minister of Energy and Mineral Resources Regulation No. 23/2017, provides a statutory mechanism for geothermal-related revenue allocation to eligible regional governments [28,29]. Nevertheless, production bonuses do not automatically generate enterprise upgrading, productive reinvestment, or economic embeddedness. Such outcomes depend on applicable regional budgeting rules, institutional decisions, and the effectiveness of development interventions [30,31]. Local productive control and reinvestment must therefore be assessed independently.

These functions should be implemented according to territorial capabilities, infrastructure and connectivity, institutional capacity, and project temporal dynamics (P6a–P6d). For example, supplier-development policies may have limited effects where local firms lack absorptive capacity, while construction-related procurement may not persist into operations without transferable capabilities or continuing market opportunities. Governance instruments should consequently be matched to local conditions and project phases rather than applied as uniform interventions [10,13,22,25].

Operationalization of the Five Constructs

Empirical application requires indicators that distinguish investment inputs, economic transmission channels, relational quality, territorial anchoring, and regional outcomes, as shown in Table 5. The proposed indicators are intended to guide future measurement development rather than constitute a validated instrument. Geothermal investment may be assessed through investment expenditure, project capacity, and phase-specific activities. Local economic linkage Mechanisms concern participation channels, including employment, procurement, MSME involvement, productive geothermal use, infrastructure-related opportunities, and market integration. Linkage quality requires separate measures of depth, durability, breadth, and interconnection. Appropriate indicators include verified capability upgrading, continuity or renewal of economic relationships, participation distribution, and documented collaboration across distinct linkage mechanisms. These indicators describe relational characteristics and must not be substituted for local ownership or reinvestment.

Table 5. Proposed operationalization of the five constructs.

Construct	Proposed Indicators and Units	Methods and Potential Sources	Proposition
Geothermal Investment	Annual investment (IDR/year); installed capacity (MW); project phase (category)	Developer reports, project records, ESDM documents	P1
Local Economic Linkage Mechanisms	Local employment (%); host-region procurement (% or IDR/year); participating MSMEs (number); productive-use activities (number)	Workforce and procurement records, enterprise surveys, developer reports	P1–P2
Linkage Quality	Depth: verified upgrading (%); durability: contract renewal (%); breadth: eligible-participant distribution (%); interconnection: documented cross-mechanism initiatives (number)	Longitudinal supplier data, training records, procurement records, interviews	P2–P3
Economic Embeddedness	Locally controlled productive assets (%); local reinvestment rate (%); strategic decisions exercised locally (%)	Beneficial-ownership records, enterprise financial data, governance interviews	P3–P4, P7
Local Economic Transformation	Non-geothermal value-added growth (%/year); regional labor productivity (IDR/worker); productive diversification (index)	BPS regional statistics, enterprise data, longitudinal regional analysis	P4, P7

Note: Indicators are theory-derived and have not been validated. Host-region boundaries, observation periods, eligible populations, and denominators must be specified before measurement. Linkage quality captures relational characteristics; Economic embeddedness captures territorial ownership, control, and reinvestment; Local economic transformation captures structural regional outcomes. Governance functions and boundary conditions should be measured separately when testing P5 and P6.

Economic embeddedness instead concerns local beneficial ownership, effective control over productive activities, territorial reinvestment of economic returns, and strategic decision-making. Local economic transformation captures broader regional changes, particularly non-geothermal productive diversification, labor productivity, and changes in sectoral economic structure. Distinguishing these measures is essential for testing P3 without making the relationship between Linkage quality and economic embeddedness tautological.

Monitoring Design and Empirical Application

A future monitoring system should distinguish baseline conditions, intermediate economic processes, and longer-term structural outcomes. Baseline assessment should document regional economic structure, supplier capabilities, productive ownership, infrastructure, and institutional capacity. Subsequent observations should track linkage participation, capability upgrading, relationship continuity, local productive control, reinvestment, and diversification using consistent geographical boundaries and denominators.

Observation periods should reflect geothermal project phases, since exploration, construction, operation, and expansion create different demands and opportunities [4,13]. Enterprise records, procurement data, ownership information, institutional monitoring, and regional statistics could support longitudinal or comparative analysis, subject to accessibility and reliability.

The proposed monitoring architecture also provides a basis for examining P1–P7. Investment and linkage data inform P1; upgrading and relational indicators inform P2; independently measured linkage quality and economic embeddedness inform P3; and territorial retention combined with structural outcomes inform P4. Governance implementation, contextual variation, and longer-term trajectories inform P5–P7.

Particular priority should be given to evaluating whether improvements in linkage quality precede changes in productive ownership, control, or local reinvestment. Observed associations

must be interpreted cautiously because wider economic trends, institutional differences, and project-phase dynamics may offer alternative explanations.

Sokoria and other Indonesian geothermal regions could provide settings for future application, provided that suitable baseline data, comparable observation periods, and project-specific evidence are available. No empirical claim is made that Sokoria currently exhibits a particular level of linkage quality, economic embeddedness, or local economic transformation. The framework's policy and monitoring implications therefore remain proposed applications requiring contextual adaptation and empirical validation.

Limitations and Future Research

This study has three principal limitations. First, the policy-enabled conceptual framework was developed through purposive, theory-driven literature synthesis rather than an exhaustive systematic literature review. The available records do not support reconstruction of a complete database-search and screening process. Accordingly, no claims are made regarding systematic-review completeness, formal thematic coding, intercoder reliability, or quantitative evidence aggregation. The framework reflects theoretically relevant source integration rather than a verified comprehensive evidence inventory [23,24]. Second, the proposed relationships are conceptual and have not been validated through primary data collection, statistical estimation, or empirical hypothesis testing. The analytical sequence does not establish causal direction, exclude alternative developmental pathways, or demonstrate the effectiveness of particular governance instruments. Project phases, regional capabilities, institutional arrangements, and wider economic conditions may alter the strength and timing of the proposed relationships. Third, the discriminant validity of linkage quality and economic embeddedness remains untested. Although the framework distinguishes relational characteristics from territorial ownership, productive control, and reinvestment, this separation requires independent measurement and empirical examination.

Future research should therefore prioritize P3, testing whether stronger linkage quality predicts subsequent increases in economic embeddedness under identifiable institutional and territorial conditions. Research should first assess construct reliability and discriminant validity using non-overlapping indicators. Particular attention should be given to cases where technically sophisticated, durable economic linkages coexist with limited local ownership or reinvestment, since such evidence could challenge the proposed relationship.

An appropriate research design would combine longitudinal procurement and supplier records, enterprise ownership information, reinvestment data, regional statistics, and interviews with economic actors. Repeated observations could distinguish relationship continuity from territorial anchoring and subsequent structural transformation. Comparative and mixed-methods approaches should consider alternative explanations, baseline differences, and project-phase effects before interpreting observed relationships causally. Following P3, research could assess capability upgrading and structural outcomes through P2 and P4, examine investment-linkage relationships and differentiated governance through P1 and P5, and investigate contextual moderation through P6. Longer-term observation is required for P7 to determine whether territorial productive anchoring corresponds to movement toward anchor-economy characteristics. Sokoria in Ende Regency, East Nusa Tenggara, offers a potential initial research setting, subject to access to reliable project, enterprise, and regional data. Comparative investigation could consider other Indonesian geothermal areas, including Dieng or Ulumbu, where suitable case comparability can be established. These locations should not be assumed equivalent in project phase, infrastructure, economic structure, or governance capacity.

Finally, future evidence should be used to refine, reject, or reconfigure the proposed relationships, including potential direct pathways and feedback effects. Until empirical

validation is undertaken, the framework remains a theory-building contribution rather than an established causal explanation of geothermal-led local economic transformation.

Conclusions

This study developed a policy-enabled conceptual framework explaining how geothermal investment may contribute to sustained local economic transformation through economic linkage mechanisms, linkage quality, and economic embeddedness, under differentiated governance functions and contextual boundary conditions. The framework advances a conditional account of geothermal-led development: investment matters when project-generated opportunities become capable, durable, and locally anchored productive activities. Its central analytical distinction is between linkage quality- the depth, durability, breadth, and interconnection of economic relationships- and economic embeddedness, reflected in local productive control, reinvestment, and decision-making. Strong relationships may persist without territorial value retention; conversely, locally controlled enterprises may remain weakly integrated into geothermal supply chains. This separation provides a testable basis for explaining divergent development trajectories rather than assuming that investment or procurement automatically produces structural change. For policy, the framework directs attention to three complementary functions: coordination to connect opportunities, capability enabling to support upgrading, and institutionalization to sustain relationships and create conditions for territorial anchoring. Their effects depend on regional capabilities, infrastructure, institutional capacity, and project phases. Monitoring should therefore distinguish investment inputs, linkage participation, relational characteristics, territorial retention, and broader diversification. Priority should be given to longitudinal tests of P3 using non-overlapping indicators, followed by comparative assessment of the remaining propositions. Sokoria offers a potential illustrative research setting, not evidence of a confirmed enclave or anchor-economy trajectory. The framework remains provisional pending empirical validation.

Supplementary Materials: Supplementary materials for this study are available at: https://journals.grimsa.org/index.php/gjset/article/view/143/130.

Funding: This study does not receive external funding.

Ethical Clearance: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No primary empirical datasets were generated or analyzed in this conceptual study. The theoretical sources supporting the proposed framework are identified in the reference list. The original historical literature-screening and coding records are not available as a complete, reproducible dataset. Therefore, no independent study-level evidence inventory is claimed.

Acknowledgments: The authors acknowledge the academic support and scholarly discussions provided by Darma Persada University during the development of this conceptual framework.

Conflicts of Interest: All the authors declare no conflicts of interest.

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