

Beyond the First Ripple:
RIPPLE-4 as a Mechanism-Based Recursive
Policy-Appraisal Framework for Small Open States

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Saint Lucia Policy Analysis

Working Paper | Version 1.0

7 August 2026

Evidence and policy-context cutoff: 6 August 2026

SaintLuciaPolicy.org

DOI: <https://doi.org/10.5281/zenodo.21838896>

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Abstract

Policy appraisal commonly identifies direct costs, benefits, and implementation requirements while representing actor adaptation, cross-system transmission, and policy-created future states less consistently. This paper develops RIPPLE-4 – Recursive Impact Pathways, Politics, Leverage, and Exposure – as a mechanism-based framework for tracing consequences through four analytic orders: direct incidence, participant adaptation, system propagation, and inherited state change. Four-level consequence maps and ripple methods have clear precedents; originality is not claimed for the number four or the metaphor. The contribution is to type pathways by mechanism, update policy state recursively, code evidence edge by edge, treat coupling and loop-closure time as measurable moderators, and connect analysis to monitoring and revision rules. The framework is developed through abductive conceptual synthesis and a structured, focused comparison of six purposively selected episodes in Mauritius, Barbados, Jamaica, Maldives, Grenada, and Vanuatu. These mechanism probes illustrate capability formation, market creation, mobile-capital response, concentration, state-contingent adaptation, and external-gatekeeper spillovers; they are not a representative sample or causal-effect estimate. The paper advances eight testable propositions and replaces a composite risk score with a transparent critical-tail profile to limit false precision. A Saint Lucia application shows how the framework can represent interactions among citizenship policy, asylum pressure, and foreign mobility decisions without reducing a multicausal event to one domestic cause. RIPPLE-4 is offered as a middle-range appraisal architecture whose incremental value should be tested against standard appraisal and unstructured consequence mapping.

Keywords: policy appraisal; policy feedback; small states; small open economies; systems thinking; adaptive governance; causal mechanisms; Saint Lucia

Beyond the First Ripple: RIPPLE-4 as a Mechanism-Based Recursive Policy-Appraisal Framework for Small Open States

Public decisions are usually announced in the grammar of direct effects. A subsidy lowers a price, a tax raises revenue, a concession attracts investment, a rule changes conduct, or a project creates an asset. These statements may be correct at the point of delivery and still be poor descriptions of the policy that ultimately exists. Households substitute. Firms reprice, reorganise, lobby, delay, or relocate. Officials ration scarce administrative attention. Banks alter credit conditions. Political coalitions form around benefits and losses. Foreign governments, carriers, correspondent banks, and insurers revise access. Temporary revenue finances commitments that later become difficult to remove. The system receiving an intervention is therefore not passive; it changes in response and becomes the initial condition for the next decision.

This problem is well recognised in several bodies of scholarship. Merton (1936) established a classical account of unanticipated consequences. System dynamics studies feedback, nonlinearity, and policy resistance (Sterman, 2001). Policy-feedback research asks how public policies reshape resources, incentives, interpretation, and later political possibilities (Pierson, 1993). Political economy and institutional analysis examine strategic response, distribution, commitment, and path dependence (Acemoglu, 2003; Pierson, 2000). Adaptive-planning approaches design pathways and adjustment points under deep uncertainty (Haasnoot et al., 2013; Quay, 2010). Contemporary appraisal guidance also calls for behavioural response, wider impacts, uncertainty, and evaluation to be considered (HM Treasury, 2026; Organisation for Economic Co-operation and Development [OECD], 2025).

The unresolved problem is operational integration. Existing approaches illuminate different portions of the causal sequence, but an appraisal team still needs a bounded way to

distinguish direct delivery from behavioural response, transmission across connected systems, and changes to the state inherited by future governments. This need is especially acute where a small number of institutions, infrastructures, skills pools, firms, public balance sheets, and foreign relationships perform multiple economic roles. Scholarship on small states documents high volatility and structural vulnerability but also wide variation in resilience and performance (Briguglio et al., 2009; Easterly & Kraay, 2000; World Bank, 2017). Size alone is not destiny. The relevant mechanisms include openness, concentration, low redundancy, institutional thinness, and exposure to external permissions.

This paper asks: *How can policy appraisal represent adaptive and recursive consequences in small, highly open states without claiming more precision or causal certainty than the evidence supports?* It answers by developing RIPPLE-4 – Recursive Impact Pathways, Politics, Leverage, and Exposure. The framework separates four kinds of consequence:

1. direct incidence generated by the instrument;
2. adaptation by participants and other strategically relevant actors;
3. propagation across markets, organisations, infrastructures, political relationships, and balance sheets; and
4. inherited changes in capabilities, obligations, institutions, coalitions, credibility, natural assets, or the feasible option set.

The contribution is not the discovery that indirect effects, ordered consequences, ripple maps, or feedback exist. It is a proposed synthesis and operating protocol that makes actor response mandatory, distinguishes mechanism from elapsed time, recursively updates inherited state, identifies re-entry into shared nodes, treats durability and reversibility as separate attributes, and requires the analysis to alter a decision instrument or its governance. RIPPLE-4 is

intended to complement, not replace, cost–benefit analysis, regulatory impact assessment, distributional analysis, the Futures Wheel, Ripple Effect Mapping, system-dynamics modelling, scenario analysis, or adaptive pathways.

The paper proceeds by locating the framework within adjacent literatures, explaining the abductive theory-building design and the limits of the comparative illustrations, defining the four-order model and appraisal workflow, and deriving eight propositions for empirical testing. Six policy episodes then serve as structured mechanism probes, followed by a focused Saint Lucian application. The discussion sets out the framework’s contribution, boundary conditions, relationship to Sovereign Option Theory, and validation agenda. A practitioner protocol and evidence codebook appear in the appendices, while an accompanying workbook supplies the edge-level case matrix.

Conceptual Foundations and Literature Position

Unanticipated Consequences, Feedback, and Policy Resistance

Merton’s (1936) account of unanticipated consequences directs attention to incomplete knowledge, error, immediate interests, basic values, and self-defeating predictions. The important implication is not that consequences are unknowable; it is that purposive action is embedded in causal chains that exceed the actor’s initial representation. Morell (2005) extends this concern into evaluation practice, while de Zwart (2015) shows why unintended and unanticipated consequences should not be treated as synonyms.

RIPPLE-4 also has direct procedural predecessors. *The Futures Wheel* maps first-, second-, and higher-order direct and indirect consequences in cascading rings (Bengston, 2016). Chalecki and Gleick (1999) explicitly organise climate and water-resource consequences from first through fourth order. *Ripple Effect Mapping* is an established participatory and retrospective

evaluation method for documenting intended and unintended programme effects (Kollock et al., 2012). These works mean that neither concentric consequence mapping, “ripple” terminology, nor the use of four levels can bear the present paper’s novelty claim.

System dynamics makes related insights operational by modelling stocks, flows, delays, nonlinear relationships, and reinforcing or balancing feedback. Sterman (2001) argues that policies frequently disappoint because decision makers misperceive feedback and ignore delayed responses. Causal-loop diagrams are useful but can also be ambiguous and should not be mistaken for validated causal models (Richardson, 1986).

Policy-feedback theory moves the causal arrow in a related direction: policy is not only an outcome of politics but also a cause of later politics. Policies allocate resources, create incentives, send interpretive signals, organise constituencies, and reshape subsequent choices (Pierson, 1993). Increasing returns can make early arrangements self-reinforcing and costly to reverse (Arthur, 1989; Pierson, 2000). RIPPLE-4 incorporates these insights but uses a narrower appraisal unit: the directed causal edge connecting an instrument to an effect, an actor response, a transmitted consequence, or an inherited state.

Complexity-oriented policy analysis similarly emphasises interdependence, coevolution, emergence, and limited central control (Cairney, 2012). Deliberative policy analysis has explicitly recognised higher-order effects and the difficulty of working in interconnected policy environments (Wagenaar, 2022). RIPPLE-4 addresses a practical gap within that broad tradition: it converts four familiar levels into mechanism-typed analytic orders, supplies a coding protocol and evidence card, recursively updates inherited state, and connects causal mapping to a revised policy decision.

Adaptation, Incidence, and Strategic Response

Legal incidence does not determine economic incidence. A levy may be imposed on a firm but passed to customers, workers, suppliers, or a mobile tax base. A benefit may be captured in prices. A performance metric may redirect effort toward what is measured rather than what is valued, a dynamic associated with Campbell's law (Campbell, 1979). A government promise may alter present behaviour only if it is credible under future incentives (Kydland & Prescott, 1977). In each case, the relevant question is not merely who receives the instrument, but how capable actors revise their conduct after the instrument changes payoffs, information, status, risk, or perceived fairness.

RIPPLE-4 therefore treats participant adaptation as its own analytic order. This is a deliberate design choice. If behavioural response is folded into an undifferentiated category of "indirect effects," it is easy to jump from delivery to an assumed social outcome without identifying the actor who makes the mechanism operate. Separating adaptation also exposes differences in power. Mobile firms, organised incumbents, skilled administrators, and foreign gatekeepers usually possess larger response sets than households tied to place or dependent on a public service. The divergence between statutory and ultimate incidence should therefore increase with substitution capacity, strategic sophistication, mobility, and control of complementary assets.

Uncertainty, Irreversibility, and Adaptive Design

Uncertainty creates two opposed errors. Analysts may suppress it with a precise-looking point estimate, or treat it as a reason to omit a material pathway. Neither response is satisfactory. Irreversibility raises the value of preserving options and acquiring information before full commitment (Arrow & Fisher, 1974). Adaptive governance and anticipatory planning respond

by linking decisions to monitoring, trigger points, and institutional capacity for revision (Folke et al., 2005; Quay, 2010). Dynamic Adaptive Policy Pathways makes the timing of adaptation explicit by identifying conditions under which a policy no longer meets its objectives and planning alternative routes in advance (Haasnoot et al., 2013).

RIPPLE-4 borrows the logic of staged commitment but applies it to causal appraisal. Each material pathway is assigned an evidence status, a probability range when defensible, a leading indicator, and a control assessment. The purpose is not to force unlike outcomes into one welfare number. It is to identify which assumptions should be tested, which losses require redundancy or insurance, and which interventions should be piloted, capped, sequenced, or made reversible.

Networks, Common Nodes, and Small-State Vulnerability

Network research shows that the stability of a system depends not only on the condition of individual nodes but also on topology, concentration, common exposures, and the pathways through which shocks travel (Acemoglu et al., 2015; Haldane & May, 2011). Small-state scholarship, meanwhile, distinguishes structural vulnerability from policy-created resilience (Briguglio et al., 2009). Small states can achieve strong average income and growth, yet frequently experience greater volatility because openness and concentration amplify external shocks (Easterly & Kraay, 2000).

RIPPLE-4 connects these literatures through the proposed conditional coupling-amplification hypothesis. The claim is conditional, not universal. Coupling here means shared dependence on a capacity-constrained, common-exposure, or difficult-to-substitute node; it does not mean network density in itself. Additional connections can diversify and absorb smaller shocks under some conditions, while dense interconnection can propagate losses after thresholds

are crossed (Acemoglu et al., 2015). Where multiple policy pathways reuse the same port, utility, bank, specialist team, visitor market, foreign-exchange pool, or public balance sheet, indirect effects should become more correlated and more likely to return to a sovereign bottleneck.

Population size is only one possible antecedent. Island geography, market thinness, concentration, limited redundancy, and dependence on foreign permissions can create the same causal structure. Jamaica is therefore used later as a larger Caribbean boundary case even though it may not meet the strict definition of a small state.

Lewisian Development and Policy-Created State

W. Arthur Lewis placed causal chains, structural bottlenecks, and the use of surplus at the centre of development analysis. His instruction to examine the “causes of these causes” (Lewis, 1955, p. 11) rejects explanations that stop at investment or output. In the dual-economy model, the developmental effect of surplus depends on whether it is converted into further accumulation (Lewis, 1954). Lewis also treated industrial and agricultural transformation as interdependent: an industrial expansion that neglects food productivity can raise subsistence costs and weaken accumulation. Later, he observed that development strategies create their own institutions, power structures, infrastructure, and outlook (Lewis, 1984).

This final observation is close to what RIPPLE-4 calls inherited state. A policy may leave behind capability, debt, maintenance, legitimacy, a political constituency, a fragile natural asset, or a narrower option set. These inheritances are not merely “long-run effects.” Some arise immediately through expectations or contract, while some direct infrastructure effects take years to materialise. Causal order and time must therefore be recorded separately.

The Integrative Niche

Table 1 identifies the framework's relationship to adjacent approaches. RIPPLE-4 overlaps with each, but its proposed contribution lies in the combination of a four-order taxonomy, mandatory actor adaptation, shared-node and re-entry analysis, evidence-coded edges, and pre-authorised revision rules.

Table 1

RIPPLE-4 in Relation to Adjacent Approaches

Approach	Principal contribution	Limitation for the present problem	RIPPLE-4's distinct role
Futures Wheel and ordered-effect frameworks	Elicit cascading first- and higher-order consequences in a visible structure	Usually organise by causal distance without a common mechanism code or recursive state equation	Types edges as incidence, actor response, boundary crossing, or inherited-state change
Ripple Effect Mapping	Participatory, retrospective mapping of intended and unintended programme effects	Designed mainly for evaluation and stakeholder sense-making after implementation	Uses prospective causal hypotheses, source confidence, monitoring indicators, and revision rules
Cost-benefit and regulatory impact assessment	Counterfactual comparison, valuation, distribution, and implementation discipline	Adaptive behaviour and cross-system feedback may remain assumptions inside a net estimate	Makes the causal chain and actor response explicit before aggregation
Policy-feedback analysis	Explains how policy reshapes resources, interpretation, coalitions, and later politics	Usually explanatory rather than a bounded ex ante appraisal workflow	Codes inherited political and institutional state as an appraisal object
System dynamics	Represents stocks, flows, feedback, nonlinearities, and delays	Can require data and modelling capacity unavailable for a rapid appraisal	Supplies a qualitative-to-formal map and escalation rule for when modelling is warranted
Process tracing	Tests mechanisms within cases using diagnostic evidence	Primarily retrospective and case-specific	Adapts edge-level evidence discipline to both retrospective probes and prospective appraisal

Approach	Principal contribution	Limitation for the present problem	RIPPLE-4's distinct role
Adaptive policy pathways	Plans adjustment routes and trigger points under deep uncertainty	Begins from vulnerabilities and policy failure points rather than a general incidence taxonomy	Connects causal orders to indicators, owners, thresholds, and correction authority
Small-state vulnerability/resilience	Identifies exposure, concentration, and resilience capacity	Does not by itself map a specific policy's return pathways	Proposes coupling, recursion, and feedback-compression hypotheses at policy level

Research Design

Abductive Theory Building

This study uses *abductive theory-building through structured, focused comparison, supported by illustrative within-case process tracing*. Abduction iterates between theoretical expectations and observed puzzles to develop a framework that can explain recurring mechanisms while remaining open to revision. Case studies are valuable for concept development and mechanism discovery, but their inferential limits must be stated (Eisenhardt, 1989; Gerring, 2004). Process tracing strengthens mechanism claims when evidence connects the steps in a sequence and rival explanations are considered; temporal succession by itself is insufficient (Collier, 2011).

The framework was constructed in three stages. First, concepts were synthesised from scholarship on ordered effects, ripple mapping, unanticipated consequences, policy feedback, system dynamics, strategic response, path dependence, irreversibility, adaptive governance, and small-state vulnerability. A targeted novelty scan was used to identify close procedural predecessors; it was not a systematic review. Second, a common causal grammar was developed to distinguish delivery, adaptation, propagation, and inheritance by mechanism rather than by ring number alone. Third, the grammar was applied iteratively to historical episodes that exhibit

different mechanisms and signs. Ambiguities uncovered during application – especially the overlap between actor response and system propagation, the role of durability, and the risks of composite scoring – were used to revise the framework.

Case Selection and Scope

Six episodes were selected purposively because they satisfy four criteria: a discrete policy instrument or institutional design can be identified; authoritative documentary evidence covers more than one link in the sequence; enough time or a sufficiently sharp event exists to observe possible inherited effects; and the set provides maximum variation in mechanism. The cases are Mauritius's export-processing regime, Barbados's solar-water-heating policy package, Jamaica's bauxite levy, Maldives' resort-island tourism architecture, Grenada's natural-disaster debt clause, and Vanuatu's investor-citizenship programme.

The selection is partly outcome-visible: each episode is already known to contain a consequential adaptive or propagated effect. This creates selection bias and makes the set inappropriate for estimating frequency, average effect size, predictive accuracy, or a quantitative small-state premium. The cases are used as *mechanism probes*: can the same coding grammar represent capability formation, market formation, mobile-capital substitution, concentration, contingent adaptation, and external-gatekeeper response without erasing important differences? This is where Jamaica, whose population exceeds conventional small-state thresholds, is retained as a theoretically useful small-open-economy boundary case (World Bank, 2017).

Unit of Analysis and Coding Rules

The unit of analysis is the directed causal edge, not the country or the final outcome. Each edge records source and destination nodes, order, actor, affected ledger, mechanism, sign, time, persistence, evidence status, source, rival explanations, reversibility, shared-node

dependence, external control, and three separate confidence judgements: measurement confidence, causal confidence, and transferability.

Four evidence-status labels are used:

1. **Observed:** directly reported administrative, legal, contractual, or outcome evidence.
2. **Attributed estimate:** a quantitative or causal estimate reported by a named source, without independent adoption as fact by this paper.
3. **Analytical inference:** an interpretation that connects observations through a stated mechanism.
4. **Scenario:** a prospective possibility whose occurrence and magnitude remain uncertain.

Measurement confidence concerns whether the node is reliably observed. Causal confidence concerns whether evidence supports the stated link rather than mere sequence. Transferability concerns whether the mechanism is likely to operate under the institutional and structural conditions of a target jurisdiction. High measurement confidence can coexist with only medium or low causal confidence.

The order rules are defined by mechanism:

1. **O1 – direct incidence:** a result mechanically or legally generated by the instrument, without requiring a discretionary response by another actor.
2. **O2 – adaptation:** a choice by an affected or strategically relevant actor in response to changed incentives, information, risk, status, or expectations.
3. **O3 – propagation:** a consequence that crosses into another market, organisation, policy domain, infrastructure, political relationship, or balance sheet because of O1 or O2.

4. **O4 – inherited state:** a change that survives at least one relevant decision or budget cycle, becomes contractually, politically, institutionally, ecologically, or physically costly to reverse, or materially alters later feasible choices.

An action can have several attributes but receives one primary order based on the rule above. For example, an airline's route decision is O2 when the focus is the airline's response; its effect on tax revenue or hotel employment is O3 because the consequence crosses systems. A direct constitutional amendment is O1 even if durable; durability is recorded separately and may also establish an inherited-state node when it constrains a later choice. Time-to-onset, duration, and reversibility are therefore independent fields.

Source Protocol and Reproducibility

Primary legislation, official administrative records, contracts, and contemporaneous government or intergovernmental reports are preferred for direct facts. Peer-reviewed research and high-quality institutional studies are used for causal interpretation and comparison. Each material quantitative statement is dated. Current Saint Lucian claims use evidence available through 6 August 2026.

The accompanying case-evidence workbook publishes the preliminary edge matrix and codebook. It does not report intercoder reliability because no independent second coding has yet been completed. The entries should be treated as a transparent analytical record, not as a validated dataset. A later validation study should preregister the codebook, blind coders to outcomes where feasible, and report agreement and adjudication.

The RIPPLE-4 Framework

Two Layers: Causal Model and Appraisal Workflow

The name has two related but distinct layers. **RIPPLE-4** denotes the analytic model – Recursive Impact Pathways, Politics, Leverage, and Exposure represented through four mechanism-typed orders. **RIPPLE** also supplies the six-step appraisal workflow:

1. **R – Reference the decision:** specify the instrument, objective, counterfactual, constraints, affected population, evidence date, review date, and end condition.
2. **I – Identify immediate incidence:** distinguish legal receipt or payment from likely economic incidence and opportunity cost.
3. **P – Predict participant adaptation:** identify relevant actors, their incentives and capabilities, and at least one self-interested and one behaviourally plausible response.
4. **P – Propagate through coupled systems:** trace material responses across seven ledgers.
5. **L – Locate leverage, lock-in, and limits:** identify shared nodes, thresholds, irreversibility, scarce capabilities, recurring commitments, and actors outside domestic control.
6. **E – Engineer evaluation and evolution:** assign indicators, owners, review dates, thresholds, safeguards, and authority to continue, adjust, pause, or stop.

The four analytic orders answer *what mechanism is being represented*. The six operations answer *how an appraisal team should construct and govern the analysis*.

Four Mechanism-Typed Orders

Table 2

Definitions and Coding Tests for the Four Analytic Orders

Order	Definition	Coding test	Common error
O1: Direct incidence	Mechanical, legal, fiscal, administrative, or physical result generated by the instrument	Would the effect occur without another actor making a discretionary response?	Treating statutory incidence as final economic incidence
O2: Adaptation	Behavioural or strategic response to changed payoffs, information, risk, status, or expectations	Which actor chooses differently, and why?	Assuming recipients remain passive or choosing only the preferred response
O3: Propagation	Transmission across a market, organisation, policy domain, infrastructure, political relationship, or balance sheet	Which boundary or ledger does the effect cross?	Calling every later event “third order” without naming the mechanism
O4: Inherited state	Material change in the state carried into a later decision cycle	What capability, constraint, obligation, coalition, asset, expectation, switching cost, or feasible option has changed?	Equating “fourth order” with “far in the future”

The labels are not a priority claim and do not imply a chronology, magnitude ranking, or mutually exclusive ontology. A rapid foreign response may be O2 or O3, while a delayed infrastructure output may remain O1. An edge receives one primary order for reproducibility and may receive secondary mechanism tags. O4 is the material counterfactual state difference carried into a later cycle; it can be produced by an O1, O2, or O3 pathway when persistence or switching-cost conditions are met.

Four is also a decision-oriented boundary, not a claim that causal chains end after four links. The number is retained because it distinguishes delivery, endogenous response, boundary-

crossing transmission, and state inheritance in a compact protocol – not because four-level consequence mapping is new (Bengston, 2016; Chalecki & Gleick, 1999). A pathway is extended when a material unresolved mechanism remains. When it returns to an earlier node, it is represented as a feedback loop rather than an indefinitely numbered list. Mapping stops when remaining pathways are immaterial under a disclosed threshold, duplicate an existing effect, fall outside the decision boundary with justification, or cannot be distinguished from background variation.

Seven Ledgers and the Counter-Entry Discipline

Propagation is checked across seven ledgers: households and wellbeing; firms and production; government; the external account; finance; institutions and politics; and natural or infrastructure assets. These are search prompts, not claims that systems have clean boundaries. A single effect may appear in more than one ledger, but it must be recorded once as an outcome and cross-referenced to prevent double counting.

The framework uses a counter-entry discipline rather than an accounting identity. Every claimed benefit is checked for resource costs, opportunity costs, distributional transfers, displaced risk, foregone options, and future liabilities. The check may reveal a countervailing entry, but it does not presume that welfare is zero-sum: a policy can create genuine net social value by reducing a distortion, coordination failure, or avoidable risk. Every apparent diversification benefit is checked for common dependencies. Every revenue forecast is paired with a behavioural tax base. Every new asset is paired with maintenance, skills, resilience, and eventual replacement. Every target is paired with an anti-gaming measure. The purpose is to expose material counter-entries where they exist, not to manufacture an offsetting loss for every gain.

Effect Cards and Evidence-Coded Edges

Each material edge receives an effect card containing: outcome and actor; low, central, and high magnitude where defensible; onset, lag, and duration; named mechanism; conditional probability range; evidence status and source; winners and losers; persistence and reversibility; leading indicator; and domestic control. An arrow that says only “incentive leads to growth” is incomplete. A valid edge names who invests, substitutes, reallocates, learns, coordinates, or withdraws, and identifies the evidence that would strengthen or weaken that mechanism.

For a sequential pathway, the probability of the complete chain is:

$$P(E_1 \cap E_2 \cap E_3 \cap E_4) = P(E_1) \times P(E_2 | E_1) \times P(E_3 | E_1, E_2) \times P(E_4 | E_1, E_2, E_3).$$

This expression does not assume independence and should not be relabelled as $P(E_4)$ unless E_4 is defined as impossible without all preceding events. Common causes, shared infrastructure, and strategic responses require joint scenarios rather than mechanical multiplication of convenient point estimates.

Formal Intuition, Context, and Recursion

Let P_t be the policy instrument at decision cycle t , P_t^0 the stated no-policy or alternative-policy counterfactual, S_t the inherited state across the seven ledgers, A_t the relevant actor configuration, N_t the network of cross-system relationships, and X_t material background conditions and shocks that are not caused by P_t within the chosen decision boundary. X_t may include external shocks, common causes, background trends, and independent actor behaviour. For a specified policy and context, the first three orders can be represented as:

$$O1_t = f_1(P_t, S_t, X_t)$$

$$O2_t = f_2(O1_t, A_t, S_t, X_t)$$

$$O3_t = f_3(O1_t, O2_t, N_t, S_t, X_t)$$

$$S_{t+1}(P_t, X_t) = g(S_t, O1_t, O2_t, O3_t, X_t)$$

$$O4_t(P) = S_{t+1}(P_t, X_t) - S_{t+1}(P_t^0, X_t).$$

The state produced under the selected policy becomes the initial condition for the next decision cycle. A change over time is not, however, automatically a policy effect. Only material, comparable state components that satisfy the inherited-state coding rule are retained as O4. The subtraction is component-specific; it does not place unlike ledger entries on a common scale or aggregate them into a welfare index. In prospective appraisal, the two state paths may be evidence-coded scenarios rather than estimated causal effects. Rival explanations and uncertainty about the counterfactual must remain explicit.

This notation makes two forms of recursion visible. The realised state under the selected policy becomes S_{t+1} , while the counterfactual difference identifies which inherited changes are hypothesised to be policy attributable. The functions can be strategic, nonlinear, discontinuous, and scenario dependent.

The coupling-amplification hypothesis concerns shared-node dependence rather than connectivity in general. Holding the direct policy impulse and external shock constant, greater dependence on a small number of capacity-constrained or common-exposure nodes should increase positive co-movement, return exposure, and possible tail propagation when the relevant links carry effects in the same direction. Diversifying, substitutable, or countercyclical connections may instead dampen transmission. Network density therefore has no unconditionally signed effect.

Recursive-path density is proposed as a descriptive map property: the share of pre-specified, evidence-supported paths, up to a stated maximum length, that enter a designated critical-node set, leave it, and return. A weighted version may be used only when path-generation

rules and weights are defined before viewing outcomes. Otherwise, map expansion and analyst discretion will manufacture apparent recursion.

Loop-closure time is the corresponding temporal measure: the elapsed time from a policy impulse until a specified effect returns to an earlier node or designated state variable. External dependence, node concentration, rapid information, and short transaction chains are hypothesised to reduce loop-closure time. None of these concepts follows automatically from population size; they concern topology, redundancy, substitutability, and control.

Uncertainty Without a Pseudo-Precise Index

The framework does not multiply ordinal judgements into a cardinal “critical-tail index.” Multiplication would imply scale properties and calibration that have not been established. Instead, analysts publish a *critical-tail profile* with six separate dimensions: probability range, severity, persistence, irreversibility, coupling, and control deficit. A rights, safety, debt, or ecological boundary remains a constraint rather than a small weighted term. Where outcomes can be defensibly expressed in common units, conventional expected-value or cost–benefit analysis should be performed. Where they cannot, the disaggregated profile is the result.

Weak evidence does not imply a zero weight. It widens the probability range, lowers confidence, increases the value of information, and strengthens the case for staging or reversibility. The decision posture should be justified in words: approve with monitoring; pilot or stage; redesign, insure, or hedge; or reject. No numerical threshold is claimed to be validated in this paper.

The Governance Test

A causal map has practical value only if it changes the instrument, sequence, scale, eligibility rule, financing, contract, safeguard, metric, trigger, owner, or timing. For every

material pathway, the decision record should identify a leading indicator one causal order upstream of the harm, a responsible owner, a review date, and the legal and financial authority to respond. This converts a one-shot forecast into an adaptive decision rule.

Theoretical Propositions

The framework yields eight propositions. They are directional claims for later testing, not findings established by the six cases.

P1 – Adaptation and incidence migration. The divergence between statutory or direct incidence and ultimate economic incidence increases with affected actors' substitution capacity, mobility, strategic sophistication, and control of complementary assets.

P2 – Conditional coupling amplification. Holding the direct policy impulse and external shock constant, greater shared dependence on capacity-constrained or common-exposure multi-use nodes increases the expected co-movement and possible tail propagation of policy effects. Diversifying, substitutable, or countercyclical connections attenuate propagation; network density alone has no unconditionally signed effect.

P3 – Recursive-path density. Policies with a larger share of pre-specified pathways returning to critical public, financial, infrastructural, or external-account nodes generate greater contingent fiscal and implementation exposure.

P4 – Loop-closure time. Greater external dependence, node concentration, information speed, and shorter intermediary chains reduce the time between direct intervention and a return signal at an earlier node.

P5 – Inherited-state persistence. State changes persist more strongly when they are reinforced by sunk costs, legal embedding, learning effects, coordinated expectations, political organisation, or high switching costs; policy withdrawal will then fail to restore the pre-intervention state along the original path.

P6 – Irreversibility and staged commitment. As uncertainty, irreversibility, and control deficit increase, staged and reversible designs with pre-authorised review triggers have greater decision value than otherwise comparable one-shot commitments.

P7 – Rent conversion. Temporary or volatile policy rents create durable developmental gains only when institutions convert them into productive capability, buffers, resilient assets, or debt reduction; financing recurring commitments instead increases fiscal-ratchet exposure.

P8 – External-gatekeeper spillover. When a state monetises or relies on an asset whose value depends on foreign permission, weak safeguards can induce a foreign response that imposes diffuse costs on residents who did not participate in the original transaction.

Table 3

Constructs, Observable Implications, and Possible Disconfirmation

Construct	Observable implication	Evidence that would weaken the claim
Incidence migration	Mobile or strategically capable actors shift costs, timing, location, or form after intervention	Ultimate incidence remains close to statutory incidence across high-mobility settings
Conditional coupling amplification	Shared dependence on a capacity-constrained or common-exposure node predicts greater co-movement or tail propagation after controlling for the initiating impulse and shock.	Shared-node dependence does not predict propagation after accounting for capacity, substitutability, link direction, and common causes.
Loop-closure time	Return signals arrive sooner where external dependence and intermediary chains are short	Comparable pathways exhibit no latency difference across levels of openness or concentration

Construct	Observable implication	Evidence that would weaken the claim
Staged commitment	Triggered, modular, or contingent designs enable earlier correction with lower stranded cost	Staging adds delay and cost without improving decisions or reducing harmful persistence
Incremental appraisal value	RIPPLE-4 identifies material effects missed by baseline appraisal at an acceptable false-positive rate	Blind back-tests show no improvement after accounting for analyst time and complexity

Structured Comparative Illustrations

Reading the Cases

The six episodes are not rankings of national wisdom and do not establish that the named instrument alone caused the inherited state. Each vignette asks the same focused questions: What was the reference decision? What was the direct incidence? Which actor adapted? Through which system did the effect propagate? What durable state or option changed? Which rival explanations limit causal confidence? The accompanying workbook separates observed facts, attributed estimates, and analytical inferences edge by edge.

Table 4

Maximum-Variation Mechanism Probes

Case	Reference decision	Recursive mechanism	Principal inherited-state question	Main causal caution
Mauritius	Export-processing regime from 1970	Capability and coalition formation	Did temporary preference and tax advantages help create export capability?	Institutions, education, sugar rents, exchange policy, and networks were complementary causes

Case	Reference decision	Recursive mechanism	Principal inherited-state question	Main causal caution
Barbados	Multi-instrument solar-water-heating package	Market formation	Did coordinated demand, supply, finance, and quality measures normalise a local technology?	Technology costs, energy prices, entrepreneurship, and building stock also influenced diffusion
Jamaica	1974 bauxite production levy	Mobile-capital response	Did rent capture alter later location and investment decisions?	Labour disruption, macro policy, oil shocks, and pre-existing diversification confound attribution
Maldives	One-island–one-resort tourism architecture	Success-induced concentration	Did a premium model also reinforce fiscal, external, and ecological exposure?	Tourism dependence is not caused solely by spatial separation
Grenada	Natural-disaster clause in restructured debt	Precommitted contingent adaptation	Did an ex ante trigger change post-disaster liquidity timing?	Liquidity relief is not debt forgiveness or proof of welfare gain
Vanuatu	Investor-citizenship programme	External-gatekeeper response	Did foreign withdrawal of a complementary permission socialise programme risk?	Post-visa programme and fiscal effects require continuing observation

Mauritius: Temporary Advantage and Capability Formation

Mauritius enacted an Export Processing Zones regime in 1970 that combined customs and tax treatment with access to external markets. Entry and employment in export manufacturing increased substantially, including formal employment for many women. Domestic capital, sugar earnings, education, infrastructure, exchange-rate management,

commercial networks, and political stability complemented the statutory regime (Frankel, 2010; Subramanian & Roy, 2001; World Bank, 1989).

RIPPLE-4 represents the direct incidence as a changed investment and customs regime. The adaptive step is firm entry, labour recruitment, and reallocation of domestic and foreign capital. Propagation occurs through learning, export-management capability, foreign exchange, and an organised constituency with an interest in the regime. The possible inherited state is not a claim that the EPZ single-handedly created later finance, tourism, or information services. It is the narrower proposition that a temporary advantage, when joined to complementary institutions and reinvestment, can leave productive capability and political support for further outward-oriented activity.

The case illustrates P7 but does not validate it. It also reveals distributional ambiguity: rapid job creation coexisted with gendered wage differences and later vulnerability in garments. A first-order replication strategy – copy the tax concession – would omit the complementary system that made capability conversion plausible.

Barbados: Policy as Market Architecture

Beginning in the 1970s, Barbados used a package of import-duty treatment, differential taxation, public procurement, tax deductions, finance, guarantees, local manufacture, and installation capability to encourage solar water heating. Over time the technology diffused widely and a domestic industry emerged (Economic Commission for Latin America and the Caribbean, 2019; Rogers, 2016; U.S. Department of Energy, 2015).

The direct effect was a change in relative price and public demand. Households, lenders, installers, and manufacturers then adapted. Their joint response propagated through supplier investment, consumer learning, maintenance capability, and social familiarity. The candidate

inherited state is a market in which the technology, skills, and expectations persisted beyond a single rebate.

This is not evidence that one fiscal measure caused every installation or engineering saving. Energy prices, entrepreneurship, product quality, credit, technology costs, and the housing stock are rival or complementary explanations. The analytic lesson is that adoption policy has both demand and supply sides. A subsidy without quality assurance, finance, installer capability, grid or utility response, and access for tenants may deliver equipment without creating a resilient market.

Jamaica: The Relevant Actor's Choice Set Was Global

Jamaica introduced a bauxite production levy in 1974 to capture a greater share of mineral rents from a vertically integrated industry. Public revenue increased sharply. In the same period, production and Jamaica's world share fell as multinational firms adjusted global portfolios; the U.S. General Accounting Office reported that Jamaica's share of world bauxite production declined from about 19% to 13% between 1974 and 1976, while its alumina share declined from about 9% to 6% (U.S. General Accounting Office, 1980).

The observation does not identify the levy as the sole cause. Labour disputes, an industrial accident, oil shocks, domestic macroeconomic policy, and diversification already underway elsewhere also mattered. The defensible mechanism claim is therefore conditional: the levy changed the relative return to Jamaican production within a global portfolio and contributed to an environment in which firms had incentives to shift activity.

RIPPLE-4's direct node is rent capture. The adaptive node is not "the mine pays"; it is the multinational group reallocating output, investment, contracts, or timing across jurisdictions. Propagation reaches exports, foreign exchange, employment, and fiscal expectations. The

inherited-state risk arises when new capacity is sunk elsewhere, so a later tax change does not automatically restore the previous investment base. This boundary case supports the plausibility of P1 and shows why a revenue forecast requires a behavioural tax base.

Maldives: Success Can Create the Next Constraint

Maldives developed a distinctive one-island–one-resort model that supported privacy, product differentiation, and high-end tourism. Tourism became a dominant source of output, exports, and public revenue. Before the COVID-19 shock, it accounted for nearly one-third of GDP, almost half of budget revenue, and more than 80% of exports according to a World Bank update; real GDP then contracted by 33.5% in 2020 when international travel stopped (World Bank, 2022). The World Trade Organization (2024) continues to describe the resort model as central to Maldives’ tourism success.

RIPPLE-4 separates two claims. First, spatial separation plausibly supported a premium product and foreign investment. Second, national dependence on tourism, together with expenditure commitments, import dependence, and debt, transmitted a sectoral stop into a fiscal and external shock. The pandemic demonstrates concentration exposure; it does not prove that spatial separation alone caused that exposure. Geography, global travel, public spending, debt, and limited diversification are important mediators.

The inherited-state question is therefore not whether the tourism model “worked.” It is whether the capabilities, obligations, land-use patterns, ecological pressures, and fiscal expectations created around its success narrowed later options. The case is consistent with P2 and P7 while illustrating their boundary conditions: the same design feature may generate both value and vulnerability, and gross activity is not the same as retained domestic value.

Grenada: Designing the Adaptation Before the Shock

Grenada's 2015 sovereign-debt restructuring included a natural-disaster clause in its international bond. The contract linked payment deferral to a pre-specified, externally verified trigger. After Hurricane Beryl in July 2024, the clause was activated. The IMF reports that the November 2024 and May 2025 payments were deferred and added pro rata to the bond's lump-sum principal payments due at maturity in 2030. The government also drew a World Bank catastrophe facility and received a large parametric insurance payout. The IMF estimated Beryl's physical damage at about 16.5% of GDP (International Monetary Fund, 2025).

The mechanism is unusually observable. The instrument is the state-contingent contract. Its direct effect is the payment pause after the verified trigger. Propagation occurs through the timing of public cash flow alongside other disaster-finance instruments. The inherited state includes a later repayment obligation and a demonstrated contractual precedent. The evidence supports the cash-flow mechanism but does not prove how much austerity, default risk, or welfare loss was avoided relative to a counterfactual.

The case illustrates P5 and P6: the adjustment rule, verifier, and consequence were specified before the shock, when bargaining capacity was greater, while the deferred obligation entered the next fiscal state. It also sets a boundary. A debt pause transfers liquidity across time; it is not debt forgiveness, a substitute for debt sustainability, or a complete disaster-finance strategy.

Vanuatu: External Permission and Policy-Induced Mobility Spillover

Vanuatu's investor-citizenship programmes generated substantial non-tax revenue. The product's value depended partly on visa-free access granted by other jurisdictions. European institutions identified risks associated with investor citizenship, including screening and security

concerns, suspended visa-free treatment beginning in 2022, and permanently removed Vanuatu from the European Union's visa-exempt list in December 2024 (Clerides et al., 2025; Council of the European Union, 2024).

The direct effect of the domestic programme was foreign-currency revenue and the conferral of citizenship. Applicants, intermediaries, and fiscal authorities adapted to programme incentives. The pathway propagated outside Vanuatu because a foreign gatekeeper controlled a complementary asset – visa-free access. Withdrawal of that permission changed the mobility of ordinary passport holders as well as the product sold to investors.

This paper calls that distributional consequence a *policy-induced mobility spillover*: programme-related reputational or security risk is socialised across all holders of the passport, including people who did not participate in or benefit directly from a transaction. The permanent visa requirement is observed; future programme demand and fiscal adjustment are not yet fully observed. The case therefore illustrates P8 while requiring continued evidence and careful separation of foreign findings from the paper's own causal claims.

Cross-Case Interpretation

The cases show that the taxonomy can represent mechanisms with different signs. Mauritius and Barbados emphasise capability and market formation. Jamaica and Vanuatu emphasise strategic response by mobile or external actors. Maldives shows how success and exposure can arise from the same system architecture. Grenada shows a policy that anticipates adaptation rather than discovering it after a shock.

The common pattern is not that every intervention generates a large fourth-order effect. It is that the appraisal result changes when analysts identify the actor who responds, the boundary crossed, the shared node or permission involved, and the state inherited. Because the cases were

chosen for visible recursive effects, they cannot establish how often the framework will add useful information or how many false positives it may generate. That question belongs to prospective and blind back-testing.

Focused Saint Lucia Application: Citizenship, Asylum Pressure, and Foreign Mobility

Saint Lucia offers a current, high-stakes application of external-gatekeeper analysis. On 5 March 2026, the United Kingdom introduced a visit-visa requirement for Saint Lucian nationals. The official explanatory memorandum identified two material concerns rather than a single cause. It reported 360 asylum claims by Saint Lucian nationals from January 2022 through December 2025, including 128 claims made at the UK border. It also described Saint Lucia's Citizenship by Investment Programme as high risk, cited approximately 5,642 programme applications in 2023–2024 – a 423% increase over the preceding year – and welcomed recent reforms while expressing concern about historical volume and misuse (UK Home Office, 2026). The visa rule took effect on 5 March, with transitional arrangements ending on 16 April 2026.

RIPPLE-4 prevents two opposite errors. The first would attribute the UK decision wholly to the citizenship programme, ignoring asylum pressure and the foreign authority's own policy judgement. The second would treat the visa decision as an exogenous event unrelated to domestic programme design. A properly coded map retains both pathways and their uncertainty.

The reference decision is the scale, eligibility, due diligence, intermediary governance, and information-sharing architecture of the citizenship programme. Within this programme-centred map, O1 includes citizenship grants and fiscal receipts. O2 includes applicant and intermediary responses to price, processing time, marketing, and controls. Programme-related information, screening concerns, banking effects, and reputational signals may then propagate across domestic and foreign institutional boundaries as O3.

Asylum pressure requires a parallel causal path. Claims by nationals who are not shown to be programme participants are not consequences of the citizenship programme and should not be coded as O3 effects of it. For an appraisal centred on citizenship policy, that independent pressure enters as X_t , an observed contextual co-cause of the United Kingdom's assessment. If asylum-related policy were itself the reference decision, claimant behaviour would be coded O2 and its effects on border administration and foreign assessment would be coded O3.

The United Kingdom's visa decision is an O2 choice by an external gatekeeper responding to information and pressures from more than one pathway. Its consequences for ordinary travel, programme demand, and foreign relations are O3 transmissions. The resulting visa environment may be recorded as an O4 state of the combined system when it persists into a later decision cycle. The portion attributable to the citizenship programme alone is not identified by the present evidence and remains an evidence-coded analytical hypothesis. The decision is outside Saint Lucia's command but strategically responsive within the larger system.

This application yields a concrete appraisal requirement. Programme evaluation cannot end with applications, grants, and net fiscal revenue. It should also monitor concentration by intermediary and origin, due-diligence exceptions, refusals and revocations, information-sharing performance, asylum and border indicators, foreign-government concerns, banking access, and the allocation of volatile receipts. Fiscal safeguards and external-trust safeguards are complements: a prudent investment rule does not repair weak screening, while excellent screening does not prevent a volatile windfall from financing sticky expenditure.

The application remains analytical, not a causal evaluation of Saint Lucia's programme. It uses the UK's stated reasons as attributed official evidence and does not claim that RIPPLE-4

predicted the event before it occurred. Its value is diagnostic: it shows why foreign permissions and nonparticipant spillovers belong inside the policy boundary.

Discussion

What Is Original – and What Is Not

RIPPLE-4 does not originate the study of indirect effects, four-level consequence chains, ripple mapping, feedback, strategic behaviour, systemic risk, path dependence, or adaptive policy. The Futures Wheel, Ripple Effect Mapping, and ordered-effects literature are acknowledged direct predecessors. The framework's defensible originality lies in their reconfiguration into a prospective, mechanism-based and recursively updating protocol: participant adaptation is mandatory; O3 requires an explicit boundary crossing or loop; O4 is the state carried into the next cycle; coupling and loop-closure are testable moderators; every edge carries evidence and confidence fields; and the map must translate into indicators, owners, triggers, safeguards, or exit rules.

This combination matters because adjacent methods solve different problems. A cost-benefit analysis may value an effect once identified, but it does not automatically discover the strategic actor or common node. System dynamics can represent feedback in greater depth, but many policy teams lack the data and modelling capacity to build a calibrated model for every decision. Process tracing strengthens retrospective causal inference but is not ordinarily an ex ante Cabinet workflow. Adaptive pathways provide a powerful logic for changing course under uncertainty, while RIPPLE-4 supplies a general causal taxonomy for deciding which developments should trigger that change.

The framework's intended niche is therefore middle range. It is more disciplined than an unstructured consequence elicitation and less demanding than a full simulation. It should

function as a search and governance protocol, with escalation to specialist modelling or evaluation when the map identifies material nonlinearities, shared failures, irreversible harms, or strategic responses.

Boundary Conditions

The framework is most likely to add value when at least one of the following is present: mobile or strategic actors; a bottleneck or common balance sheet; a recurring commitment funded by volatile revenue; a foreign gatekeeper; a nonlinear threshold; material irreversibility; low redundancy; or a high likelihood that the policy alters coalitions, capability, trust, or later options. It may add little to decisions whose effects are genuinely local, short, reversible, and well observed.

Smallness should not be treated as an all-purpose explanation. A small jurisdiction can have redundant digital services, diversified markets, or unusually strong administrative capability. A larger state can contain highly coupled regions or sectors. The conditional coupling-amplification hypothesis should therefore be tested with direct measures of shared-node dependence, capacity, substitutability, external dependence, and administrative capability rather than population alone.

Four orders are also not ontological categories. Analysts may disagree on coding, especially at the O2–O3 boundary or when a direct institutional intervention is immediately durable. The published rules reduce but cannot eliminate judgement. Reliability testing is essential before the framework is used for comparative scoring.

Relation to Sovereign Option Theory

RIPPLE-4 is complementary to, but distinct from, Sovereign Option Theory (SOT). SOT addresses how a small state can preserve option value while making credible, time-bounded

commitments under uncertainty (Michel, 2026). RIPPLE-4 addresses what the policy system may do after an intervention and which inherited conditions change the next decision. Put simply, RIPPLE-4 diagnoses causal pathways; SOT helps choose and govern commitments in light of those pathways. Citing the relationship also marks the boundary between the two contributions and reduces the risk of presenting overlapping material as independent inventions.

Validation Agenda

The next stage should test incremental usefulness, not merely collect more persuasive examples. A credible programme would:

1. preregister the order definitions, evidence codebook, stopping rule, and materiality threshold;
2. blind back-test 10–20 completed policy decisions using only information available before each decision;
3. compare RIPPLE-4 maps with the contemporaneous appraisal or a standardised baseline RIA/CBA;
4. measure recall of material adverse and beneficial effects, false positives, calibration or Brier loss where probabilities are elicited, coding agreement, analyst time, and whether the analysis would have changed the decision;
5. compare node concentration and return pathways across small and larger jurisdictions exposed to similar instruments or shocks; and
6. prospectively pilot the framework on several decisions with published indicators and review triggers.

Evidence would weaken the theory if node concentration fails to predict propagation after relevant controls; independent analysts cannot classify orders or material pathways with

acceptable agreement; staged rules do not improve adaptation or reduce stranded cost; or RIPPLE-4 performs no better than standard appraisal after accounting for added time and complexity.

Limitations

This paper has five principal limitations. First, the cases are purposive and outcome-visible, creating hindsight and selection bias. Second, the framework has not been subjected to independent coding or predictive validation. Third, the four-order boundary is pragmatic, and classification contains judgement. Fourth, the formal notation is illustrative; no common unit, calibrated response matrix, or validated recursion metric is estimated. Fifth, the Saint Lucia application concerns a politically salient and evolving event. It relies on official attributed reasons available by the evidence cutoff and should be updated if material documents or policy changes emerge.

Conclusion

The first-order description of a policy is often accurate and incomplete. What matters next is who adapts, how the response crosses systems, whether several pathways reuse the same critical node, and what institutions, obligations, capabilities, permissions, or losses the next decision maker inherits.

RIPPLE-4 provides a bounded way to ask those questions. It separates direct incidence, adaptation, propagation, and inherited state; records time and durability independently; exposes common nodes and external gatekeepers; preserves uncertainty through evidence-coded edges and a multidimensional critical-tail profile; and requires named indicators, owners, triggers, and correction authority. Its contribution is an operational synthesis, not a claim to have invented indirect effects.

The historical illustrations demonstrate plausibility and scope, not causal validation. The framework will earn a stronger scholarly status only if it can be coded reliably, forecast material consequences better than a credible baseline, and change decisions without generating an unacceptable burden of speculative pathways. That is the appropriate standard for the next stage of research.

Declarations

Funding. This research received no external funding.

Competing interests. The author declares no competing interests.

Data and materials availability. The study uses public secondary and administrative sources cited in the manuscript. A preliminary edge-level coding matrix and codebook accompany this paper as supplementary material. No confidential or personal-level dataset was created.

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Appendix A

RIPPLE Rapid Appraisal Protocol

Reference the Decision

Write one sentence naming the instrument, eligible actors, scale, start date, review date, and end condition. Record the objective, success measure, no-policy counterfactual, evidence date, and non-negotiable constraints.

Map Direct Incidence

Identify who legally receives, pays, administers, or is excluded. Then identify likely economic incidence and opportunity cost. Test each claimed benefit for resource costs, opportunity costs, distributional transfers, displaced risk, foregone options, and future liabilities. Record a counter-entry when the evidence supports one; do not presume that every benefit is offset by an equal loss.

Predict Adaptation

For each central actor ask: If this intervention changes costs, benefits, risk, information, status, or perceived fairness, what becomes the actor's best response, and what lower-effort shortcut might actually be used? Include affected households and firms, administrators, financiers, political actors, and relevant external gatekeepers.

Propagate Through the Ledgers

Trace each material adaptive response through households and wellbeing; firms and production; government; the external account; finance; institutions and politics; and natural or infrastructure assets. Name the mechanism on every edge and cross-reference duplicate outcomes.

Locate Leverage, Lock-In, and Limits

Identify shared nodes, scarce skills, common balance sheets, single-point infrastructure, recurring commitments funded by volatile revenue, nonlinear thresholds, foreign permissions, and effects that are physically, contractually, politically, or ecologically costly to reverse.

Engineer Evaluation and Evolution

For each material pathway identify a leading indicator, publisher, frequency, owner, review date, response threshold, and authority to continue, adjust, pause, or stop. Record the exact policy modification produced by the analysis.

Appendix B

Effect Card

Table B1

Effect Card Fields

Field	Required entry
Outcome and actor	What changes, for whom, and where?
Order	O1 direct incidence, O2 adaptation, O3 propagation, or O4 inherited state
Magnitude	Low, central, and high range in physical units where defensible
Timing	Onset, lag, duration, and evidence vintage
Mechanism	Why does the source node cause the destination node?
Probability	Conditional range and assumptions; omit decorative decimals
Evidence	Observed, attributed estimate, analytical inference, or scenario; exact source
Confidence	Measurement, causal, and transferability confidence separately
Distribution	Winners, losers, nonparticipants affected, and capacity to organise
Persistence/reversibility	Temporary, persistent, or costly/effectively irreversible
Coupling	Shared node, common cause, or correlated exposure
Observability	Leading indicator one causal order upstream
Control	Prevent, insure, adapt, negotiate, or absorb
Decision consequence	Instrument, sequence, scale, finance, safeguard, trigger, owner, or stop rule changed

Appendix C

Critical-Tail Profile

For every low-probability but potentially material pathway, report the following dimensions separately:

1. probability range and evidentiary basis;
2. severity in the affected unit and distribution;
3. persistence;
4. reversibility or irreversibility;
5. coupling to other systems or common nodes; and
6. control deficit, including dependence on external actors.

Do not multiply ordinal judgements into a cardinal score. State the proposed response – prevention, redundancy, insurance, staging, monitoring, negotiation, or non-adoption – and the reason it is proportionate.

Appendix D

Red-Team Questions

1. Which central actor is still treated as passive?
2. What response is lawful or formally compliant but defeats the policy's purpose?
3. Which pathway uses the same port, utility, bank, specialist team, visitor market, public balance sheet, or foreign permission as another pathway?
4. Does any reported benefit impose another actor's cost, liability, risk, or foregone option?
5. What would make the effect change sign across time or groups?
6. Which result is an observation, which is an attributed estimate, and which is the analyst's inference?
7. What rival explanation fits the sequence?
8. What outcome is duplicated across ledgers or paths?
9. Which assumption can be tested at small scale before full commitment?
10. What evidence would cause the analyst to retract the pathway or change the decision?

Appendix E

Worked Demonstration: Grenada's Natural-Disaster Clause

This demonstration applies the codebook to the narrowest pathway supported by the documentary evidence. It illustrates classification and counterfactual discipline; it does not estimate the clause's net welfare effect or the amount of austerity, default risk, or social loss avoided.

$$P_t + X_t \rightarrow O1 \rightarrow O3 \rightarrow O4$$

Here, P_t is the natural-disaster clause included in Grenada's 2015 restructured international bond. X_t is Hurricane Beryl and the externally verified loss condition. The World

Bank catastrophe facility and parametric insurance payout are parallel disaster-finance pathways, not consequences of the bond clause.

Table E1

Evidence-Coded Grenada Pathway

Stage	Directed pathway	Mechanism	Evidence and caution
O1: Direct incidence	Verified trigger and pre-agreed clause → two scheduled bond payments deferred	State-contingent contract activation	Observed contractual outcome. The payment consequence was specified before the shock.
O3: Propagation	Payment deferral → near-term sovereign cash outflow postponed	Intertemporal cash-flow transmission	IMF estimate: US\$12 million, or 0.9% of 2024 GDP. Welfare effects are not identified.
O3: Parallel finance	CCRIF payout and World Bank Cat-DDO → additional immediate liquidity	Layered disaster-finance transmission	Observed financing environment; these are parallel pathways and are not caused by the bond clause.
O4: Inherited state	Deferred payments → principal carried to the 2030 maturity	Liability postponement, not forgiveness	Observed inherited obligation; the exact counterfactual welfare effect is not estimated.

Note. Hurricane Beryl is contextual X_t rather than a policy consequence. The IMF estimated physical damage at approximately 16.5% of GDP. Grenada also drew US\$20 million through the World Bank Catastrophe Deferred Drawdown Option and received a US\$55.5 million CCRIF payout; these instruments contributed to the same disaster-finance environment but remain separate from the bond-clause effect to avoid double counting (International Monetary Fund, 2025).

Table E2*Completed Effect Card: Deferred Bond Payments Entering the 2030 Debt State*

Field	Completed entry
Outcome and actor	Grenada's government postpones two scheduled bond payments; bondholders retain a contractual claim shifted to the 2030 maturity.
Order	Primary order: O4 inherited state. Source incidence: O1 payment deferral. Intermediate transmission: O3 government cash-flow timing.
Magnitude	Approximately US\$12 million, or 0.9% of 2024 GDP, according to the IMF. No low–high range is reported.
Timing	Payments scheduled for November 2024 and May 2025 were deferred and added pro rata to principal due at the bond's maturity in 2030.
Mechanism	A verified disaster-loss threshold activates the bond's pre-agreed payment-deferral terms.
Probability	Realised conditional event. The paper does not report or invent an ex ante probability for threshold activation.
Evidence	Payment dates and capitalization at maturity: observed contractual outcome. Dollar and GDP magnitudes: IMF attributed estimates.
Confidence	Measurement: high for dates, terms, and reported amount. Causal: high for trigger-to-deferral. Transferability: medium because replication depends on contract terms, verification, creditor acceptance, and market access.
Distribution	Government receives near-term liquidity timing; creditors receive payment later while retaining their claim. Household and welfare effects depend on the use of fiscal space and are not identified here.
Persistence/reversibility	The obligation persists to the 2030 maturity unless repaid or renegotiated. The deferral is temporary liquidity relief paired with a durable repayment entry.
Coupling	The public balance sheet is the shared node. The bond clause, World Bank facility, and CCRIF payout respond to the same disaster but have distinct triggers and financial consequences.

Field	Completed entry
Observability	Upstream indicators are the modelled-loss determination, trigger verification, scheduled debt-service dates, and published treatment of deferred amounts.
Control	Ex ante: negotiate the trigger, verifier, duration, capitalization, and maturity treatment. Ex post: administer the clause, disclose the liability, and incorporate the 2030 obligation into debt management.
Decision consequence	Future contingent-debt contracts should state the trigger, verifier, affected payments, capitalization rule, maturity treatment, reporting duty, and relationship to the wider disaster-finance and debt-sustainability strategy.

The demonstration shows why the four orders should not be read as four elapsed periods.

The external shock is not a policy consequence; the payment pause is direct contractual incidence; its cash-flow effect crosses into the government ledger; and the capitalized repayment enters a later fiscal state. A valid appraisal would compare this pathway with the same disaster under a bond without the clause and would keep the effects of parallel insurance and catastrophe-finance instruments separate.