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When the Average Hides the Weakest Link *A Formal Definition of Ecosystem Viability under Voluntary Interdependence*

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Research Article

Keywords: ecosystems, viability, participation, weakest link, compensatory aggregation, formal model

Posted Date: November 16th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11332969/v1

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Additional Declarations: No competing interests reported.

Abstract

Ecosystem leads usually decide whether to keep investing in partners from a single composite figure, such as average partner satisfaction. A composite figure lets strong results among some partners offset weak results among others, so an ecosystem can lose a partner it cannot replace while the figure still looks sound. This paper defines ecosystem viability as a region of a state space of participation gaps, rather than as a score. A compensatory region based on a weighted aggregate is compared with a weakest-link region based on a designated critical set. The two regions coincide only in degenerate cases, and neither contains the other unless all weight sits on critical actors. At a threshold of zero, a critical actor holding half the weight or less can be in complete deficit while the aggregate certifies viability. A five-actor example illustrates the results. Viability claims should report both regions.

1. Introduction

Ecosystem leads have to decide whether to keep investing in the partners on which the ecosystem depends. The decision usually rests on a single figure, such as average partner satisfaction, a retention rate or a weighted index. The literature explains why the partners matter. Their interdependence is multilateral and specific to each relationship (Adner 2017; Jacobides et al. 2018), an idea with roots in the business-ecosystem metaphor (Moore 1993), and an ecosystem lasts only while each actor continues to find participation worthwhile (Hirschman 1970; Granovetter 1978). Recent work examines how ecosystems evolve and how complementors reshape them (Adner and Lieberman 2021; Jacobides et al. 2021). It says less about how a lead should read a composite figure. The usual construction scores each actor, weights the scores by importance and compares the weighted total with a cut-off, which is the standard form of multi-attribute evaluation (Keeney and Raiffa 1976; Grabisch et al. 2009).

A figure of this kind is compensatory. Strong results among some partners offset weak results among others. The offset is harmless when the weak partner can be replaced. It is costly when the partner cannot be replaced, for example because it holds a licence, runs the only distribution channel or is the regulator. In that case the ecosystem can fail while the index stays positive, because the remaining partners are doing well, and those partners then bear part of the cost. A composite figure shows whether the ecosystem is doing well on average. It does not show whether the ecosystem can afford to lose a partner it cannot replace, and a single number cannot show which of the two has failed.

Discovery’s health ecosystem illustrates both situations. In August 2024 Vitality removed Pick n Pay from its HealthyFood benefit and replaced it with Checkers from 1 September, while Woolworths remained (BusinessTech 2024). A grocery partner was therefore replaced within a month. A regulator cannot be replaced in the same way. In 2023 the Council for Medical Schemes directed five schemes, Discovery Health Medical Scheme among them, to withdraw or qualify their announced increases, and all five complied (News24 2023).

The cause is that a single weight carries two meanings. It records how much a partner contributes to the total, and it implies how easily the partner could be replaced. These are different questions. The purpose

of this paper is to separate them, building on prior models of threshold participation, dependency and aggregation (Section 2). Three steps are taken. First, viability is defined as a region of a state space rather than as a score, so that different definitions of viability can be compared as sets. The state is built from each actor's participation gap, which is the amount by which the fairness the actor perceives exceeds or falls short of the level it needs in order to stay. Second, membership of the ecosystem is derived from a dependency predicate rather than asserted, so that the state space has a defined boundary. Third, importance and non-substitutability are kept apart. Weights govern the aggregate, and a separate critical set governs the weakest-link test. A single compensation parameter links the two rules.

Three results follow. First, the compensatory and weakest-link regions coincide only in degenerate configurations (Proposition 1), and neither contains the other unless all viability weight sits on critical actors (Proposition 5). Second, a critical actor of weight w can be in complete deficit while the weighted aggregate certifies viability at threshold γ whenever $w \leq (1 - \gamma)/2$ (Proposition 4). At the conventional cut-off $\gamma = 0$, any critical actor holding no more than half the weight can therefore fail completely without the aggregate registering it. Third, both regions are well-posed and convex, and the blended family lies between them (Propositions 2 and 3). In the five-actor example of Section 5, the weighted mean gap is + 0.04 and the compensatory rule passes, while the weakest critical actor sits at − 0.15 and the weakest-link rule fails.

Three implications follow for practice. First, a viability report should show both regions, since each rule accepts states the other rejects. Second, designating an actor as critical is a claim about non-substitutability (Barney 1991; Iansiti and Levien 2004). The claim has to be argued for and cannot be read off the weight of the actor. Third, the tolerance formula allows any weighting scheme to be audited, by stating how much failure by a critical actor the scheme can hide. The contribution of this paper is definitional and structural. Viability is not estimated for any real ecosystem, and the Discovery material above is context, not evidence. The analysis is confined to a single time slice, and entry and exit, dynamics, intervention, shocks and estimation are left to subsequent work.

Section 2 anchors the model in prior work and states what changes. Section 3 sets out the assumptions and definitions. Section 4 presents the results, Section 5 illustrates them, and Section 6 discusses implications and limits. Proofs are in Online Appendix A and code is in Online Appendix B.

2. Anchoring in Prior Models

The model combines four strands of prior work, and each supplies an element that is kept unchanged. First, threshold treatments of participation, in which an actor stays while its net position clears a personal cut-off, come from sociology and behavioural economics (Granovetter 1978; Simon 1955), and the distinction between exit and voice comes from organisational economics (Hirschman 1970). Second, dependency as the basis of relations between organisations comes from power-dependence and resource dependence theory (Emerson 1962; Pfeffer and Salancik 1978) and from work on the structure and governance of interdependence, which treats the pattern of ties, rather than the number of

actors, as what has to be managed (Adner and Kapoor 2010; Dyer and Singh 1998; Williamson 1985). Third, compensatory aggregation, in which a weighted total trades one attribute against another, is the additive form of multi-attribute evaluation (Keeney and Raiffa 1976) and an instance of the general class of aggregation functions (Grabisch et al. 2009). Its non-compensatory counterparts include elimination rules in choice (Tversky 1972; Payne et al. 1993) and weakest-link production, in which output is capped by the poorest component (Kremer 1993; Hirshleifer 1983). Fourth, viability theory contributes only the idea of a viable set as a subset of a state space (Aubin 1991). Table 1 records what each strand supplies and what is changed.

Table 1
What the model keeps from prior work, and what it changes.

Element	Prior work	Kept	Changed here
Participation	Granovetter (1978); Simon (1955); Hirschman (1970)	Actor-specific threshold; net position decides	Net position made the primitive: the gap G = PAF − PT on a common scale
Membership	Emerson (1962); Pfeffer and Salancik (1978); Adner and Kapoor (2010)	Dependency as the basis of ties	Member set derived from a threshold predicate on D, with a boundary region
Compensatory rule	Keeney and Raiffa (1976); Grabisch et al. (2009)	Weighted mean of actor-level values	Applied to gaps, and treated as one region rather than as the definition of viability
Weakest-link rule	Kremer (1993); Hirshleifer (1983)	The minimum operator	Applied over a critical set C defined independently of the weights
Viable set	Aubin (1991)	Viability as a subset of a state space	Single time slice; no viability kernel, which requires dynamics

The change is small. Both aggregation logics are kept exactly as prior work defines them. What differs is what they are applied to and how they are related. They are applied to actor-specific participation gaps rather than to attributes or task outputs, with a critical set specified independently of the weights, and they are treated as regions to be compared rather than as alternative scoring rules. This is what allows the exact statements in Section 4 about when the two logics agree. In Aubin's terminology, the region defined here plays the role of a constraint set. The viability kernel, the set of states from which a viable evolution exists, requires dynamics and lies outside a single-slice analysis.

3. Model

3.1 Notation

The participation constructs (Participation Threshold, Perceived Allocation Fairness, Allocation Outcome Equity, and Governance Promise Consistency) are those introduced in Mosala (working paper). Table 2 lists the notation.

Table 2
Notation.

Symbol	Meaning
$\hat{E}$, E_t, n_t	Candidate-actor universe; member set at time t; its size $n_t = \|E_t\|$
$D = [d_{ij}]$	Dependency matrix; $d_{ij} \in [0,1]$ is the degree to which actor i depends on actor j
τ_D	Dependency threshold for membership
$PT_{i,t}$, $PAF_{i,t}$	Participation Threshold; Perceived Allocation Fairness
$AOE_{i,t}$, $GPC_{i,t}$	Allocation Outcome Equity; Governance Promise Consistency (carried in the state, not used in the regions)
$G_{i,t} = PAF_{i,t} - PT_{i,t}$	Participation gap
w_i, W_C	Viability weight, with $\Sigma w_i = 1$ and $w_i \geq 0$; total weight on the critical set, $W_C = \Sigma_{i \in C} w_i$
$C \subseteq E_t$	Critical (non-substitutable) actors
λ, γ	Compensation parameter in [0,1]; viability threshold
$EVS^{(0)}$, $EVS^{(W)}$, WL_C, VS_λ	Unweighted mean gap; weighted mean gap; weakest-link statistic; blended statistic
$\mathcal{V}_{comp}$, $\mathcal{V}_{noncomp}$, $\mathcal{V}_\lambda$	Compensatory, weakest-link, and blended viable regions of the state space S_t

3.2 Assumptions

Table 3 states the assumptions on which the results rest, the prior work that anchors each, and the role each plays. Departures from any of them change the results in ways noted in Section 6.

Table 3
Assumptions, anchors, and roles.

Assumption	Anchor	Role in the results
A1 Common bounded scale. PT, PAF, AOE and GPC are composite indices normalised to [0,1].	Adams (1965); Colquitt (2001); Simon (1955)	Bounds G in [– 1,1]. The tolerance bound in Proposition 4 uses the floor of − 1.
A2 Participation as threshold crossing. An actor's net position is its gap G = PAF − PT, and the sign of G is what bears on continued participation.	Granovetter (1978); Simon (1955); Hirschman (1970)	Makes G the primitive from which every region is built.
A3 Dependency defines membership. An actor belongs to the ecosystem exactly when at least one dependency tie, in either direction, reaches τ_D.	Emerson (1962); Pfeffer and Salancik (1978); Dyer and Singh (1998); Adner and Kapoor (2010); Baldwin and Clark (2000)	Fixes E_t and hence the dimension of the state space S_t.
A4 Importance is not non-substitutability. Weights w govern the aggregate; a critical set C, specified separately, governs the weakest-link test.	Barney (1991); Iansiti and Levien (2004); Keeney and Raiffa (1976)	Source of the divergence in Propositions 1, 4 and 5.
A5 Single time slice with exogenous parameters. The weights, C, γ, λ and τ_D are fixed and the state is observed at one instant.	Scope condition	Excludes dynamics, entry and exit, intervention, shocks and estimation.
A6 Non-members are excluded, not zeroed. G, w and membership of C are undefined for actors that fail the membership test.	Follows from A3	Prevents a non-member's absence from being read as a zero gap.

3.3 Definitions

Definitions 1

and 2 fix the state space. For a member i, the actor state vector collects the four constructs, and the state space is the product over members:

$x_{i,t} := (PT_{i,t}, PAF_{i,t}, AOE_{i,t}, GPC_{i,t}) \in [0,1]^4$ (1)

$S_t := \times_{i \in Et} [0,1]^4$, $\dim S_t = 4n_t$ (2)

S_t is a finite product of compact convex intervals and is therefore compact and convex, the kind of regularity that classical equilibrium theory assumes of its choice sets (Debreu 1959). The dependency matrix, the weights, and the critical set are parameters, not coordinates of S_t.

Definitions 3

to 5 make membership a predicate. Let $\hat{E}$ be the fixed universe of candidate actors and $d_{ij,t} \in [0,1]$ the degree to which i depends on j at time t, with no symmetry assumed. Fix a threshold $\tau_D \in (0,1]$. An actor i is a member at time t (Definition 4) when

$\max_{j \neq i} \max(d_{ij,t}, d_{ji,t}) \geq \tau_D$ (3)

and the member set E_t collects such actors. Candidates with a non-zero but sub-threshold tie form the boundary region (Definition 5),

$\partial E_t := \{i \in \hat{E} : 0 < \max_{j \neq i} \max(d_{ij,t}, d_{ji,t}) < \tau_D\}$ (4)

which is peripheral: connected to the ecosystem but not a member. By A6, an actor outside E_t has no gap, weight, or critical status. This is stronger than assigning it a gap of zero, which would assert that its fairness exactly meets its threshold, whereas non-membership asserts that the question does not yet arise.

Definitions 6

and 7 introduce the participation gap and its trichotomy. For $i \in E_t$,

$G_{i,t} := PAF_{i,t} - PT_{i,t} \in [-1,1]$ (5)

and the surplus, threshold and deficit sets $\Sigma_t = \{i \in E_t : G_{i,t} > 0\}$, $\Theta_t = \{i \in E_t : G_{i,t} = 0\}$ and $\Delta_t = \{i \in E_t : G_{i,t} < 0\}$ partition E_t.

Definitions 8

and 9 give the two statistics on which the regions are built: the unweighted and weighted mean gaps and the weakest-link statistic. All three take values in [− 1,1].

$EVS^{(0)}(s_t) := (1/n_t) \Sigma_{i \in Et} G_{i,t}$ (6)

$EVS^{(W)}(s_t) := \Sigma_{i \in Et} w_i G_{i,t}$ (7)

$WL_C(s_t) := \min_{i \in C} G_{i,t}$ $(C \neq \emptyset)$, $WL_\emptyset(s_t) := EVS^{(W)}(s_t)$ (8)

The convention for $C = \emptyset$ follows from the definition of the critical set: with no critical actor there is no basis for departing from the compensatory reading, so the weakest-link term equals the aggregate.

Definitions 10

to 12 define the viable regions for a threshold γ. The compensatory and weakest-link regions are

$\mathcal{V}_{comp}(\gamma) := \{s_t \in S_t : EVS^{(W)}(s_t) \geq \gamma\}$ (9)

$\mathcal{V}_{\text{noncomp}}(\gamma,C) := \{s_t \in S_t : WL_C(s_t) \geq \gamma\}$ (10)

and, for $\lambda \in [0,1]$, the blended statistic and its region (Definition 12) are

$VS_\lambda(s_t) := \lambda \cdot EVS^{(W)}(s_t) + (1 - \lambda) \cdot WL_C(s_t)$ (11)

$\mathcal{V}_\lambda(\gamma,C) := \{s_t \in S_t : VS_\lambda(s_t) \geq \gamma\}$ (12)

By construction $\mathcal{V}_{\text{comp}}(\gamma) = \mathcal{V}_1(\gamma,C)$ for every C, and $\mathcal{V}_{\text{noncomp}}(\gamma,C) = \mathcal{V}_0(\gamma,C)$ whenever $C \neq \emptyset$.

4. Results

4.1 When do the two rules agree?

Proposition 1

(Limits and coincidence). Fix $\gamma \in (-1,1)$. (i) If $C = \emptyset$, then $\mathcal{V}_\lambda(\gamma,C) = \mathcal{V}_{\text{comp}}(\gamma)$ for every $\lambda \in [0,1]$. (ii) For every state, $|VS_\lambda - EVS^{(W)}| \leq 2(1 - \lambda)$ and $|VS_\lambda - WL_C| \leq 2\lambda$. Hence a state with $EVS^{(W)} \neq \gamma$ belongs to $\mathcal{V}_\lambda(\gamma,C)$ exactly when it belongs to $\mathcal{V}_{\text{comp}}(\gamma)$, for all λ sufficiently close to 1, and a state with $WL_C \neq \gamma$ belongs to $\mathcal{V}_\lambda(\gamma,C)$ exactly when it belongs to $\mathcal{V}_{\text{noncomp}}(\gamma,C)$, for all λ sufficiently close to 0. (iii) $\mathcal{V}_{\text{comp}}(\gamma) = \mathcal{V}_{\text{noncomp}}(\gamma,C)$ if and only if $C = \emptyset$ or $C = \{j\}$ with $w_j = 1$.

The two rules therefore differ in general. They agree when no actor is designated critical, because the weakest-link term then has nothing to act on, or when the entire weight sits on a single critical actor, because the aggregate then equals that actor's gap. Parts (i) and (ii) follow from the affine dependence of VS_λ on λ. For part (iii), whenever some critical actor has weight below one there is a state that the aggregate accepts and the weakest-link rule rejects (Online Appendix A).

4.2 Regularity

Proposition 2

(Non-emptiness). For every λ, w and C, $\mathcal{V}_\lambda(\gamma,C) = S_t$ if $\gamma \leq -1$, is a non-empty proper subset of S_t if $\gamma \in (-1,1]$, and is empty if $\gamma > 1$.

Proposition 3

(Structure). For fixed λ, w and C: (i) $\mathcal{V}_\lambda(\gamma,C)$ is a compact convex polytope, and $\mathcal{V}_\lambda(\gamma,C) \subseteq \mathcal{V}_\lambda(\gamma',C)$ whenever $\gamma' \leq \gamma$; (ii) $\mathcal{V}_{\text{comp}}(\gamma) \cap \mathcal{V}_{\text{noncomp}}(\gamma,C) \subseteq \mathcal{V}_\lambda(\gamma,C) \subseteq \mathcal{V}_{\text{comp}}(\gamma) \cup \mathcal{V}_{\text{noncomp}}(\gamma,C)$ for every λ.

Proposition 2

guarantees that the central object exists for every admissible weight vector and critical set. Proposition 3 describes its shape: VS_λ is concave, being a non-negative combination of a linear function and a

minimum of linear functions, so its upper level sets are convex, and part (ii) confines the blended region between the intersection and the union of the two pure regions. The proofs are short and appear in Online Appendix A.

4.3 How much can the aggregate hide?

Proposition 4

(Tolerance of the compensatory region). Let $C \neq \emptyset$, let $w_{C,min} := \min_{i \in C} w_i$, and let $\gamma \in [-1,1]$. Then

$$\min_{s \in \mathcal{V}_{comp(\gamma)}} WL_C(s) = \max\{ -1, 1 - (1-\gamma)/w_{C,min} \} \quad (13)$$

with the term $1 - (1-\gamma)/w_{C,min}$ read as $-\infty$ when $w_{C,min} = 0$. In particular the minimum equals -1 whenever $w_{C,min} \leq (1-\gamma)/2$.

At $\gamma = 0$, for example, a critical actor holding weight of one half or less can be in complete deficit (PAF = 0, PT = 1) in a state that the compensatory rule certifies as viable, provided the remaining actors sit at their ceiling. The bound is a worst case, attained at extreme states, and Section 5 reports how much of the state space is affected in a typical configuration. An equivalent statement concerns protection. A critical actor j is guaranteed a gap of at least $m > -1$ in every compensatory-viable state only if $w_j \geq (1-\gamma)/(1-m)$. Guaranteeing a gap of $m = \gamma$, the level the weakest-link rule demands, requires $w_j = 1$. No non-degenerate weighting scheme protects a critical actor.

Proposition 5

(Containment). Let $\gamma \in (-1,1)$ and $C \neq \emptyset$. (i) $\mathcal{V}_{noncomp}(\gamma,C) \subseteq \mathcal{V}_{comp}(\gamma)$ if and only if $W_C = 1$. (ii) $\mathcal{V}_{comp}(\gamma) \subseteq \mathcal{V}_{noncomp}(\gamma,C)$ if and only if $C = \{j\}$ with $w_j = 1$. (iii) Hence, if $W_C < 1$, neither region contains the other.

Each rule therefore misses something the other catches. When some weighted actor is not critical, the compensatory rule accepts states in which a critical actor has failed, and the weakest-link rule accepts states in which the non-critical actors have collapsed, since it does not look at them. Only when all viability weight sits on critical actors is the weakest-link region nested inside the compensatory one, and the regions are equal only in the singleton case of Proposition 1. Proofs are in Online Appendix A.

5. Illustration

5.1 A five-actor state

An ecosystem is considered at one instant, with five members: a platform owner, an anchor complementor, a peripheral complementor, an end-user segment and a regulator. The anchor complementor and the regulator are designated critical, $C = \{2,5\}$. Table 4 gives the constructs, the resulting gaps and the weights. The actors and values are stylised.

Table 4
A five-actor state with C = {2, 5}.

Actor	PT	PAF	G	w	Critical
1. Platform owner	0.30	0.55	+ 0.25	0.30	no
2. Anchor complementor	0.60	0.45	−0.15	0.25	yes
3. Peripheral complementor	0.40	0.50	+ 0.10	0.15	no
4. End-user segment	0.35	0.35	0.00	0.10	no
5. Regulator	0.50	0.42	−0.08	0.20	yes

The unweighted mean gap is $EVS^{(0)} = 0.024$. The weighted mean gap and the weakest-link statistic are

$$EVS^{(W)} = 0.075 - 0.0375 + 0.015 + 0.000 - 0.016 = 0.0365 \quad (14)$$

$$WL_C = \min\{G_2, G_5\} = \min\{-0.15, -0.08\} = -0.15 \quad (15)$$

At γ = 0 the compensatory rule certifies the state as viable, because 0.0365 ≥ 0, while the weakest-link rule rejects it, because − 0.15 < 0. At an intermediate compensation level the blended statistic is

$$VS_{0.5} = 0.5(0.0365) + 0.5(-0.15) = -0.05675 \quad (16)$$

so the state is not viable once even half the weight goes to the weakest link. The blended statistic is non-negative only when λ ≥ 0.804. Proposition 4 quantifies the exposure: the smallest critical weight is $w_{C,min} = w_5 = 0.20$, which is below (1 − 0)/2 = 0.5, so the minimum of WL_C over the compensatory region is − 1. The regulator could be in complete deficit in a state this weighting scheme certifies. Since $W_C = 0.45 < 1$, Proposition 5 implies that neither region contains the other.

5.2 How large is the disagreement?

Proposition 4

is a worst-case statement. To gauge how much of the state space is affected, the share of S_t on which each rule certifies viability and on which they disagree was computed, using the weights of Table 4, γ = 0, and the uniform measure on S_t (PT and PAF independent and uniform on [0,1]). Table 5 reports the results for four critical sets. This is a geometric property of the regions under a reference measure, not the probability that any real ecosystem is viable.

Table 5
Share of the state space certified by each rule (γ = 0, uniform reference measure).

Critical set	W_C	Comp. certifies	Weakest link certifies	Comp. only	Weakest link only	Comp.-certified states rejected by weakest link
C = {2, 5} (worked example)	0.45	50.1%	25.0%	29.6%	4.5%	59.2%
C = {2}	0.25	50.1%	50.1%	16.1%	16.1%	32.1%
C = {1, 2}	0.55	50.1%	25.1%	27.5%	2.5%	55.0%
C = {2, 3, 5}	0.60	50.1%	12.5%	38.8%	1.2%	77.5%

By symmetry the compensatory rule certifies about half the state space whatever the critical set. The weakest-link rule certifies a quarter of it or less when two or more actors are critical, and the share of compensatory-certified states it rejects rises with the number of critical actors, from about a third with one to over three quarters with three. The reverse disagreement, states the weakest-link rule accepts and the compensatory rule rejects, is equal in size to the forward one when a single actor is critical, as the symmetry of the reference measure requires, and falls to between about 1% and 5% of the state space when two or more are. Shares are Monte Carlo estimates from 2,000,000 draws with standard error below 0.0004.

6. Discussion

6.1 Implications

The results bear on practice in four ways. First, the critical set is a claim about the world and has to be argued for. Because importance and non-substitutability are separate (A4), an actor's weight in an aggregate is not evidence that it is critical, and a small weight is not evidence that it is dispensable. Designating C requires an argument about replaceability, of the kind the resource-based, keystone and ecosystem-bottleneck literatures make (Barney 1991; Iansiti and Levien 2004; Eisenhardt and Bingham 2017). Second, a viability claim should report both regions. A state in one region and outside the other is informative, and the direction of the disagreement says which kind of failure is being missed. Third, Proposition 4 allows any weighting scheme to be audited: given a scheme and a cut-off, it states the deepest critical-actor deficit the aggregate can certify. Fourth, setting λ is a claim about how far the ecosystem can substitute across actors, and the five-actor example shows that this claim, rather than any further fact about the actors, can decide whether the ecosystem is judged viable.

6.2 Boundary conditions and limitations

The results are conditional on the assumptions in Table 3, and the effect of relaxing each is stated here. If the constructs are normalised to a different bounded interval (A1), the tolerance bound rescales but its

logic is unchanged. If the critical set were defined from the weights, for instance as the actors above a weight cut-off (A4), the tolerance threshold would rise, but the divergence would persist unless a single actor held all the weight. Four limitations remain. First, the constructs are perceptual and their measurement is outside the scope of this paper. The model takes PT and PAF as given and says nothing about how to estimate them or how uncertain they are. Second, designating C is a judgement, and different designations yield different regions. Critical status can also shift over time as technologies and capabilities change (Adner and Lieberman 2021), which a single time slice cannot show. Third, the weakest-link rule used here is one non-compensatory form. Smoother forms, in which deficits are penalised progressively rather than tested against a cut-off, are not covered. Fourth, a region says whether a state is viable at an instant, not whether the ecosystem will remain so, and the thresholds τ_D and γ are exogenous.

6.3 Extensions

Each excluded topic builds on the definitions here. Entry and exit require a model of how a gap translates into withdrawal. Dynamics require an account of how gaps evolve, and with it the viability kernel in Aubin's sense; evolutionary treatments of ecosystem change (Jacobides et al. 2021) show the processes such an account would have to represent. Intervention requires a cost structure and an objective, and could build on formal models of platform governance such as the soft-governance analysis of Doshi and Schmidt (2024). Shock propagation requires the dependency matrix to carry transmission as well as membership. Estimation requires measurement models for the constructs. Because the definitions and propositions above are stated for a single slice, none of these extensions changes them.

7. Conclusion

This paper set out to define when an ecosystem is viable under voluntary interdependence. Viability was defined as a region rather than a score, and importance was separated from non-substitutability. Three conclusions follow. First, the two rules coincide only in degenerate cases. Second, each rule accepts states the other rejects. Third, a critical actor of modest weight can fail completely while the aggregate certifies viability. The practical lesson is to report both regions and to justify the critical set on grounds other than weight.

Declarations

Data and Code Availability

No empirical data were used in this work. The Python reference implementation that reproduces every number in Sections 5.1 and 5.2 is described in Online Appendix B and is supplied with the submission.

Declaration of Generative AI and AI-Assisted Technologies in the Manuscript Preparation Process

During the preparation of this work the author used Claude (Anthropic), a generative AI assistant, for the following purposes: drafting and restructuring the manuscript text, including its adaptation to the writing style of the author, working from samples of the author's own writing; proposing formal definitions, propositions and proofs in response to the author's specification of the framework; writing the Python reference implementation in Online Appendix B and running the numerical checks and the simulation reported in Section 5.2; and locating and checking bibliographic details of the references. The research programme, the constructs (Participation Threshold, Perceived Allocation Fairness, Allocation Outcome Equity and Governance Promise Consistency) and the shared notation were specified by the author. The numerical results were produced by executing the code in Online Appendix B and can be reproduced from it.

After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication, including the correctness of the proofs and the accuracy of the references. The AI tool is not listed as an author.

Author Contribution

All content was created and reviewed by the author

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