# Asymmetrical Equilibrium: Why Sustainable Systems Depend on Controlled Imbalance

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**Abstract**

This paper challenges the most persistent myth in systems theory: that stability is achieved through balance. In the real world, nothing alive or functional is ever in balance. A bicycle, a forest, a market, or an organization remains upright only by staying slightly wrong and continually correcting. We are documenting a bias in academic framing—the assumption that deviation equals failure. In the physical world, deviation *is* operation. The mathematics that follow are descriptive, not prescriptive: a controlled disequilibrium that survives by oscillating inside its limits. Systems collapse not when they drift, but when they mistake symmetry for safety.

**Keywords:** asymmetrical equilibrium; sustainable imbalance; deviation bias; controlled invariance; non-equilibrium dynamics

## Introduction

Systems theory has been telling the same polite lie for a century—that equilibrium is desirable. It makes the math neat and the funding proposals comfortable, but the assumption has never matched observation. The farm, the factory floor, the trading desk, and the human body all run on the same physics: they live by constant over-correction. The moment balance is achieved, throughput stops and decay begins.

This paper doesn't offer a new framework or another vocabulary of resilience. It exposes an academic habit—the worship of symmetry—and replaces it with what every operator already knows. The functional world is a managed asymmetry: energy in, energy out, always a little too much or too little of something. The equations that follow do nothing more radical than describe that condition honestly.

Readers looking for optimization strategies will find none. The point here is not how to reach equilibrium but how to avoid mistaking equilibrium for success. Deviation is not an error term; it's the heartbeat of viability. The only sustainable system is the one that never stops adjusting.

## 1 Motivation

Economics usually assumes **symmetrical equilibria**—where supply equals demand at a point.
Yet real systems (especially agro-ecological or socio-ecological) are often *stable precisely because they are not balanced.*

A managed farm, for instance, remains viable by staying in **controlled disequilibrium**—continually adjusting stocks, flows, and feedbacks to maintain robustness.

The goal: formalize **sustainable imbalance**, i.e., systems that are *stable because they keep moving.*

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## 2 Dynamic Framing

Model the system as a controlled dynamical process with disturbances:

$$\dot{x} = f(x, u, \omega), \qquad x \in \mathbb{R}^n$$

where

- $x$: system state (soil C/N, biomass, pests, cash, etc.)
- $u$: management controls (stocking rate, irrigation, rotations)
- $\omega$: external shocks (weather, prices)

Define a **balance metric** $b(x)$ (e.g. predator:prey ratio or supply–demand gap) and maintain a deliberate offset:

$$b(x) \geq \varepsilon > 0$$

The objective is *not* to drive $b(x)$ to zero but to preserve a **robust offset** away from fragility.

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## 3 Sustainable Imbalance as a Controlled Invariant Set

Let

$$\mathcal{K} = \{\, x : g(x) \leq 0,\ b(x) \geq \varepsilon \,\}$$

represent the admissible states (the *viability kernel*). A regime is *sustainably imbalanced* if there exists a policy $u(\cdot)$ such that for any $x_0 \in \mathcal{K}$,

$$x(t; x_0, u, \omega) \in \mathcal{K}, \quad \forall t \geq 0$$

despite bounded disturbances $\omega$.

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## 4 Mathematical Lenses

| Concept | Meaning | Connection |
|---|---|---|
| **Input-to-State Stability (ISS)** | Bounded shocks produce bounded states | Quantifies robustness of feedback policies |
| **Viability Theory / Controlled Invariance** | Existence of controls keeping the state in a safe set | Defines the sustainability domain |

| Concept | Meaning | Connection |
|---|---|---|
| **Non-Equilibrium Steady States (NESS)** | Systems maintained by throughput of energy/matter | Farms as dissipative structures |
| **Homeorhesis** | Return to a *trajectory* rather than a fixed point | "Stable because it keeps moving" |

Hence, sustainable imbalance = **a robustly invariant, nonequilibrium attractor** maintained by control and throughput.

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# 5 Toy Models: Managed Grass–Herbivore–Pest System

## 5.1 Common Structure

**States (core):**

$$F:\text{Forage biomass (t/ha)},\quad H:\text{Herbivore mass (t/ha)},\quad P:\text{Pest biomass (kg/ha)}$$

**Seasonal driver:**

$$R(t) = 1 + 0.5\sin(2\pi t)\quad \text{(period = 1 year)}$$

**Grazing and growth:**

$$\dot{F} = r_0 R(t) F\left(1 - \frac{F}{K_0 R(t)}\right) - \frac{gHF}{F+F_h} - \alpha PF,$$
$$\dot{H} = \eta \frac{gHF}{F+F_h} - mH - u_{\text{off}} H.$$

**Control input (shared):** $u_{\text{off}} \in [0,1]$ (herd offtake fraction).

### Variant A: Chemical Control

**Additional state and control:**

$$C:\text{Chemical load (kg/ha)},\qquad u_{\text{chem}} \geq 0:\text{application rate (kg/ha/yr)}.$$

**Pest and chemical dynamics:**

$$\dot{P} = (s_0 + \rho F)P - \gamma C P - k_P P,$$
$$\dot{C} = u_{\text{chem}} - \delta_C C.$$

**Heuristic policy (chemical reflex):**

$$H^\star(F) = \kappa F,$$
$$u_{\text{off}}(x) = k_h \max(0, H - H^\star(F)),$$
$$u_{\text{chem}}(x) = k_c \max(0,\, P - P_{\text{tol}}).$$

**Variant-A viability (illustrative):**

$$\mathcal{K}_{\text{chem}} = \{x:\ F_{\min} \leq F \leq F_{\max},\ H_{\min} \leq H \leq H_{\max},\ P \leq P_{\max}\}.$$

### Variant B: Biological Control

**Additional state and control:**

$$B : \text{Beneficial predator biomass (kg/ha)}, \qquad u_{\text{bio}} \geq 0 : \text{release rate (kg/ha/yr)}.$$

**Predator–prey augmentation:**

$$\begin{aligned}\dot{P} &= (s_0 + \rho F)P - \mu BP - k_P P,\\ \dot{B} &= \beta\,\mu BP - \delta_B B + u_{\text{bio}}.\end{aligned}$$

**Heuristic policy (ratio-keeping):**

$$\begin{aligned}H^\star(F) &= \kappa F,\\ u_{\text{off}}(x) &= k_h \max(0, H - H^\star(F)),\\ u_{\text{bio}}(x) &= k_b \max\big(0,\, \varepsilon P - B\big).\end{aligned}$$

**Variant-B offset and viability:**

$$b(x) = \frac{B}{P} \geq \varepsilon, \qquad \mathcal{K}_{\text{bio}} = \{x:\ F_{\min} \leq F \leq F_{\max},\ H_{\min} \leq H \leq H_{\max},\ P \leq P_{\max},\ B/P \geq \varepsilon\}.$$

**Interpretation.** In agricultural practice, predators are rarely treated as assets; chemistry substitutes ecological feedback with industrial reflex. Yellowstone learned the inverse: reintroducing wolves reintroduced motion; the return of instability restored stability. Chemical suppression and trophic rewilding are opposites in method but twins in meaning—they expose the cost of mistaking control for health.

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## 6 Parameter Definitions

| Symbol | Description | Units / Value |
|---|---|---|
| $r_0$ | intrinsic forage growth | 1.2 $\text{yr}^{-1}$ |
| $K_0$ | forage carrying capacity (seasonal) | 4.0 t/ha |
| $g$ | max grazing rate | 1.8 $\text{yr}^{-1}$ |
| $F_h$ | half-saturation forage | 0.3 t/ha |
| $\eta$ | forage→herbivore conversion efficiency | 0.4 (dimensionless) |
| $m$ | herbivore maintenance rate | 0.3 $\text{yr}^{-1}$ |
| $\alpha$ | pest damage on forage | 0.05 $(\text{kg/ha})^{-1}$ $\text{yr}^{-1}$ |
| $s_0$ | pest intrinsic growth | 0.8 $\text{yr}^{-1}$ |
| $\rho$ | forage-boost to pest growth | 0.2 $(\text{t/ha})^{-1}$ $\text{yr}^{-1}$ |
| $k_P$ | non-predation pest death | 0.2 $\text{yr}^{-1}$ |
| *Chemical-variant specific* | | |
| $\gamma$ | chem. effectiveness on pests | $(\text{kg/ha})^{-1}$ $\text{yr}^{-1}$ (set as needed) |
| $\delta_C$ | chemical decay rate | 0.3 $\text{yr}^{-1}$ |
| $k_c$ | chem. control gain (policy) | user-chosen |

| Symbol | Description | Units / Value |
|---|---|---|
| $P_{\text{tol}}$ | pest tolerance threshold | user-chosen (kg/ha) |
| *Biological-variant specific* | | |
| $\mu$ | predation rate of $B$ on $P$ | 0.01 $(\text{kg/ha})^{-1}$ $\text{yr}^{-1}$ |
| $\beta$ | predator conversion efficiency | 0.5 (dimensionless) |
| $\delta_B$ | predator death rate | 0.4 $\text{yr}^{-1}$ |
| $k_b$ | bio-control gain (policy) | 5.0 kg/ha/yr |
| $\varepsilon$ | ratio floor $(B/P)$ | e.g. 0.2 |
| *Management/viability* | | |
| $\kappa$ | stocking ratio $(H^\star = \kappa F)$ | 0.15 |
| $k_h$ | offtake gain | 2.0 $\text{yr}^{-1}$ |
| $F_{\min}, F_{\max}$ | forage bounds | user-chosen (t/ha) |
| $H_{\min}, H_{\max}$ | herbivore bounds | user-chosen (t/ha) |
| $P_{\max}$ | pest cap | user-chosen (kg/ha) |

*Notes:* Values provided are illustrative. Chosen units are consistent across variants; select numerical values to match site- or study-specific conditions.

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## 7 Control Design Options

- Replace heuristics with a **quadratic program (QP)** that enforces barrier constraints ($\mathcal{K}_{\text{chem}}$ or $\mathcal{K}_{\text{bio}}$).
- Add a **cash** state for costs: chemical purchases, beneficial releases, and destocking losses.
- Sweep the offset level $\varepsilon$ (bio) or $P_{\text{tol}}$ (chem) to map the cost–robustness frontier.

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## 8 Summary Formula

**Sustainable imbalance** =
controlled invariance of a nonequilibrium attractor
within offset constraints $b(x) \geq \varepsilon$.

The system's health is its **ability to stay in motion without exiting its viability basin**.

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## Closing Note

Equilibrium is a mathematical daydream. Nothing that grows, trades, or endures ever reaches it. Every real system stays alive by wobbling—by burning energy to correct its own excesses just enough to keep moving. That motion is not a flaw; it is the definition of function.

We are surrounded by institutions still trying to freeze the oscillation: regulators chasing perfect compliance, managers chasing perfect efficiency, engineers chasing noise-free control. They mistake smoothness for health. What actually keeps a system viable is roughness—slack, lag, overshoot, recovery. Remove those and the next disturbance finishes the job.

The equations in this paper are not a theory of how to achieve balance; they are a confession of how the world already works. Deviation is operation. Stability is motion. Everything else is bureaucracy pretending to be physics.

# 9 References

## References


[1] Aubin, J.-P. (1991). *Viability Theory*. Boston: Birkhäuser.

[2] Prigogine, I., & Nicolis, G. (1977). *Self-Organization in Nonequilibrium Systems: From Dissipative Structures to Order through Fluctuations*. New York: Wiley.

[3] Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4, 1–23.

[4] Waddington, C. H. (1957). *The Strategy of the Genes: A Discussion of Some Aspects of Theoretical Biology*. London: George Allen & Unwin.

[5] Godley, W., & Lavoie, M. (2007). *Monetary Economics: An Integrated Approach to Credit, Money, Income, Production and Wealth*. London: Palgrave Macmillan.

[6] May, R. M. (1973). *Stability and Complexity in Model Ecosystems*. Princeton University Press.

[7] Scheffer, M. (2009). *Critical Transitions in Nature and Society*. Princeton University Press.

[8] Levin, S. A. (1998). Ecosystems and the biosphere as complex adaptive systems. *Ecosystems*, 1(5), 431–436.

[9] Meadows, D. H. (2008). *Thinking in Systems: A Primer*. White River Junction, VT: Chelsea Green.