Regulating the Quantum Ecology

A pharmakological idea for governing quantum information technologies

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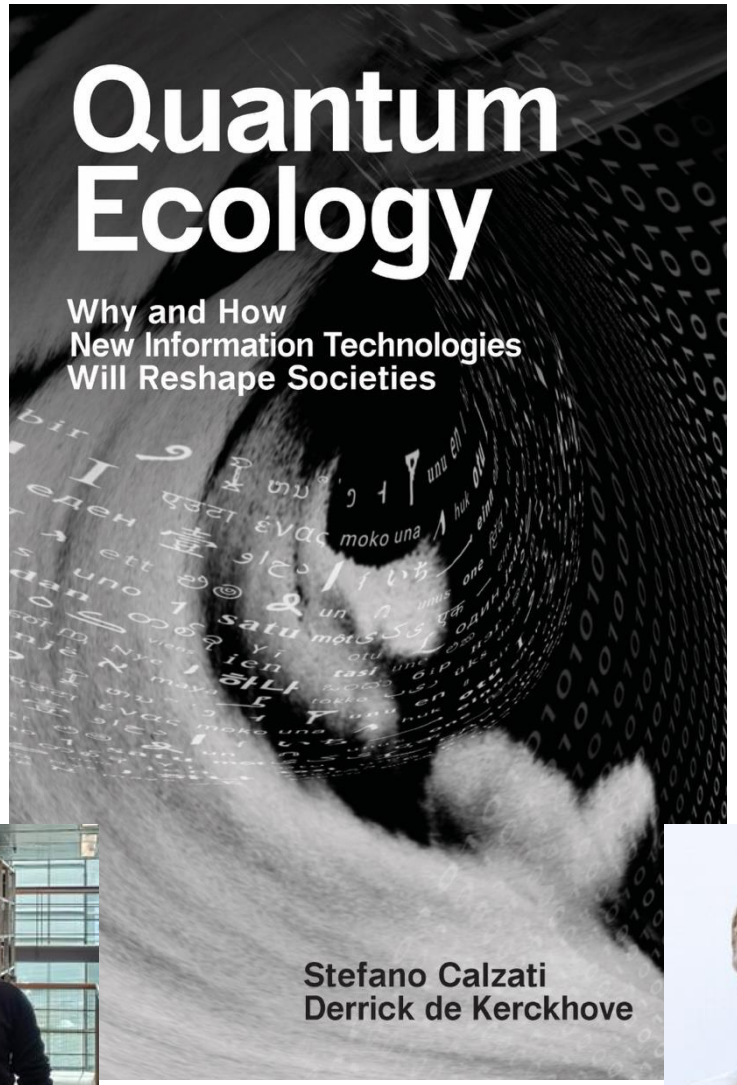


Quantum Ecology

Calzati & de Kerckhove 2024, MIT Press

Onto-epistemological framework, whose pillars are uncertainty, complementarity, nonlocality, superposition, entanglement.

Technological paradigm, pivoting around Quantum Information Technologies (QITs).

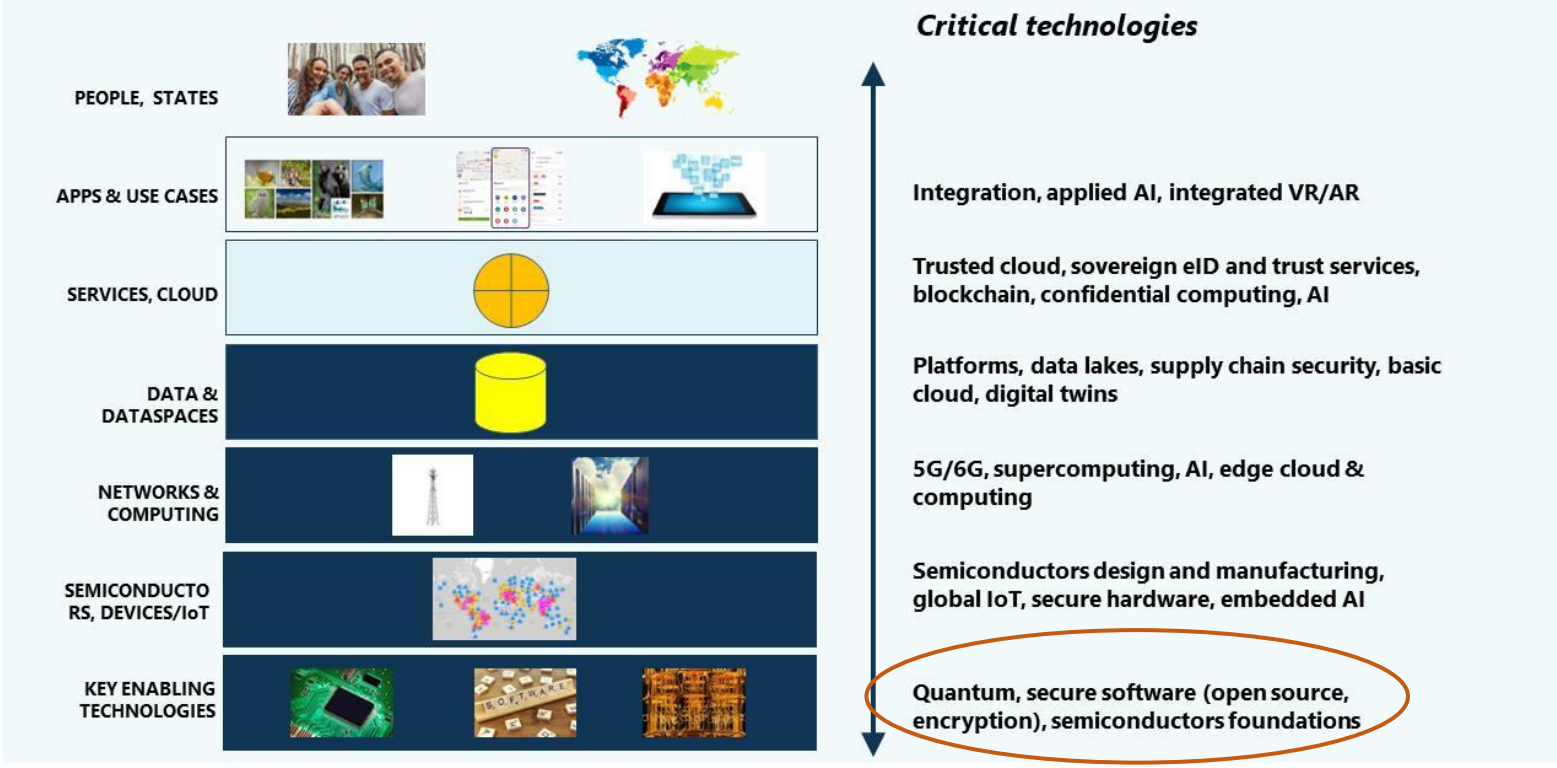
Regulating QITs

QITs as enabling (dual use) technologies

Second quantum revolution (Dowling & Milburn 2003)

→quantum **RRI** (Coenen & Grunwald 2017)

→**anticipatory precautionary** regulation (Taylor 2020)



Technology stack (Timmers 2023)

Propositions of QITs regulation: A critical review

	Johnson (2019)	WEF (2022)	Perrier (2022)	OECD (2025)	Kop (2025)
Scope	QITs	Quantum computing	QITs	QITs	QITs & AI
Dual use	(Mostly) broad meaning	Broad meaning	Both meanings	Both meanings	Narrow meaning
Framing	US-focus; multistakeholder collaboration	Multistakeholder collaboration	Multistakeholder & multilateral collaboration	Multistakeholder collaboration	Multilateral collaboration
Rationale	(Mostly) socio-economic	Socio-economic	Socio-economic & geostrategic	Socio-economic & geostrategic	Geostrategic
Stance	Adaptive	Adaptive	(Mostly) adaptive	Adaptive	Innovative
Type	Soft regulation	Values & principles	Actor-instrument framework	Values	Soft & hard regulation
Strengths	Identification of regulatory instruments	Principled co-created recommendations	Comprehensive taxonomy of actors and regulatory instruments	Technological and socio-economic granularity; collaboration-security trade-off	Comprehensive framework for geostrategic collaboration
Weaknesses	Insufficient soft regulation-only; no compliance mechanisms	Optimistic consensus by design; no compliance mechanisms	Static and idealised taxonomy; no enforcing mechanisms	No compliance or enforcing mechanisms	High-level abstraction; no enforcement mechanisms; no corporate actors

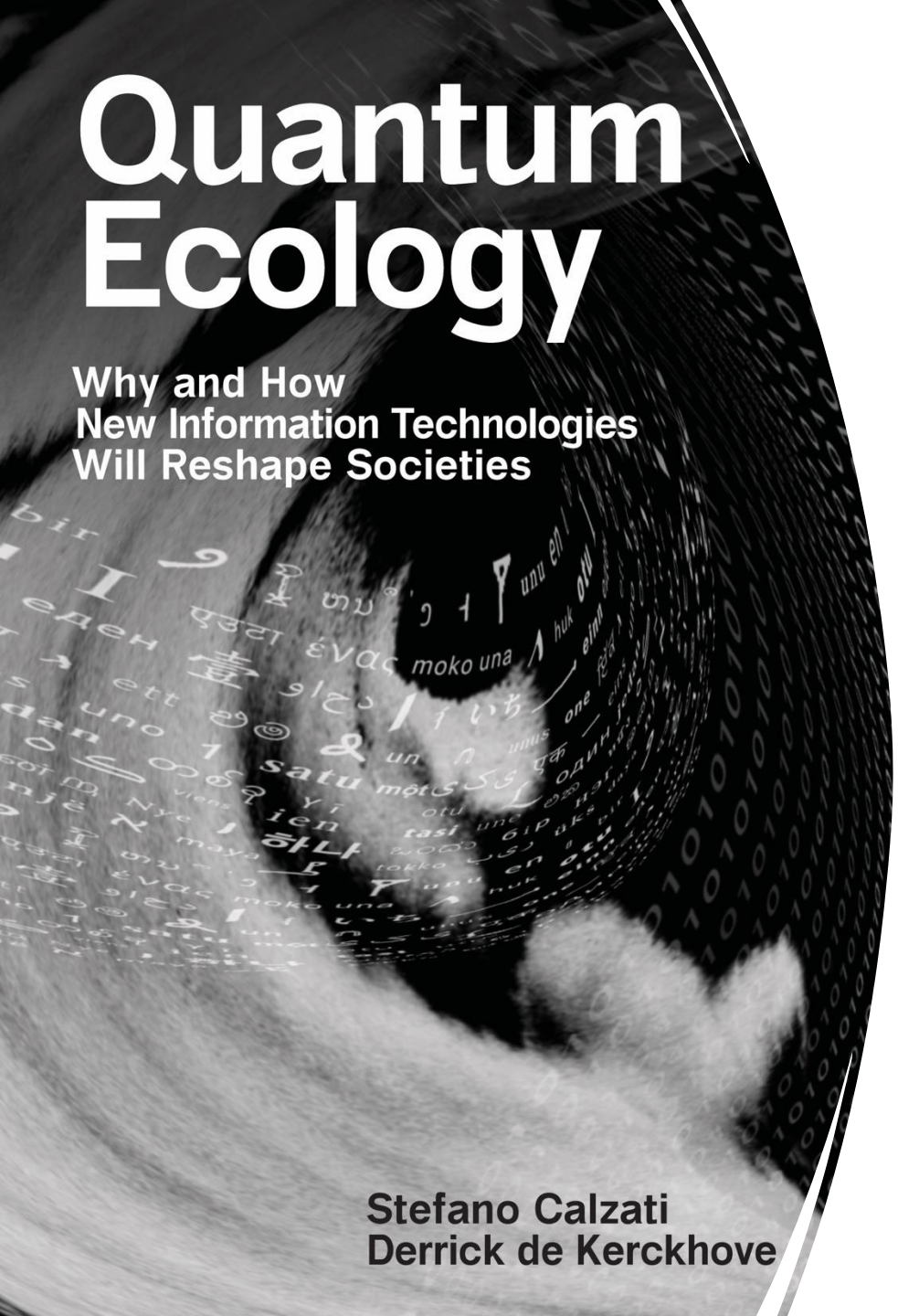
Soft to hard, increasing dual use emphasis → openness-security trade-off

Limits

- **Lack of enforceable mechanisms** to ensure the trade-off between openness and strategic autonomy

- Priority to either certain **actors** (Kop 2025), **principles** (World Economic Forum 2022; OECD 2025), or **instruments** (Johnson 2019; Perrier 2022) without a **systemic approach** for the establishment of a **global quantum polity**

→How to **enforce the systemic balance between research openness and strategic autonomy** across scales and among diverse quantum stakeholders?



Quantum Ecology

- *Onto-epistemological framework* as **communitarian**:

"Community is a 'negative' concept: *cum* + *munus* denotes a bond based on **mutual necessity**."

→A quantum race is a non-zero-sum game; it is **not** in anyone's self-interest (cf. Roussel et al 2026)

- *Technological paradigm* as **pharmakological** (Stiegler 1993)

"Every *dispositif* always contains its own resistance"

→ **Quantum principles** as operationalizable resources for governing QITs

A possible Quantum Republic (QuRe)

How to operationalize a **communitarian-pharmakological** governance of/through QITs?

- *Nuclear Non-Proliferation Treaty* & *Quantum Game Theory* (Calzati & de Kerckhove 2024; Kop 2025; Perrier & Aboy 2026)

→Quantization of game theory can generate **better-than-classical outcomes for negotiating dilemmas**, facilitating cooperation over competition (Eisert et al 1999) and equity over self-interest (Smoliński et al 2025)

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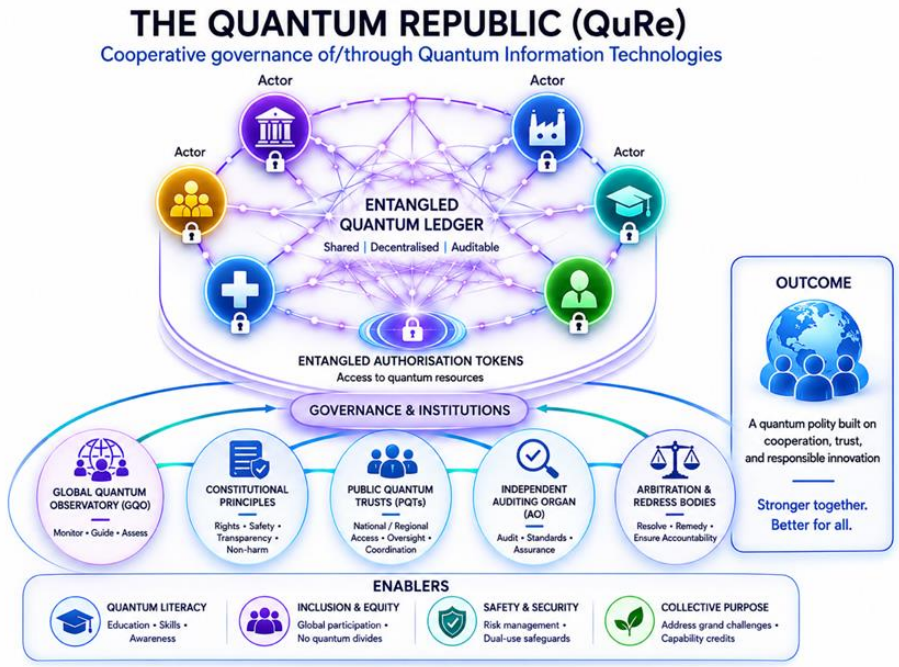
- **Republican approach** to technology governance (Susskind 2022; Calzati & van Loenen 2023; Hoeksema 2024)

→A republican governance of technology moves away from prioritizing either actors, principles, or instruments to rather enable a **systemic distribution of power**, **mutual accountability**, and **collegial decisions.**

Hybrid (quantum & classical) speculative design

- **Quantum game theory-based distributed ledger:**
  - Authorisation tokens (entangled qubits) to access and use shared quantum computation
  - Quantum zero-knowledge proof to validate declared computation
  - *Cooperation* boosts computational power for all actors; *defection* triggers a shared computational cost

- **Institutional arrangements** (based on digital republicanism):
  - *Treaty+global quantum observatory* (→ IAEA; Kop 2025)
  - *public quantum trusts* (→ public data trusts; van der Sloot & Keymolen 2022)
  - *bodies of abitration* (→ Calzati & van Loenen 2023)
  - quantum registry (→ OECD 2026; cf. patents)
  - auditing organ (→ Susskind 2022)
  - quantum communes (→ Susskind 2022; Calzati & van Loenen 2023)



Limits & further work

- **Low TRLs** of quantum computing and quantum communication
- Hard **verifiability** of quantum computation (even under ideal conditions)

- **Lack of auditing**

→standards and benchmarks as pathway (cf. earlier propositions)

- **QGT remains theoretical and based on rational agents**

→simulation of complex scenarios (e.g., information asymmetries, real-like geopolitical conditions, time-dependent scenarios, non-rational behaviours, cf. Pothos & Busemeyer 2022)

- **Refinement** of identified institutional arrangements

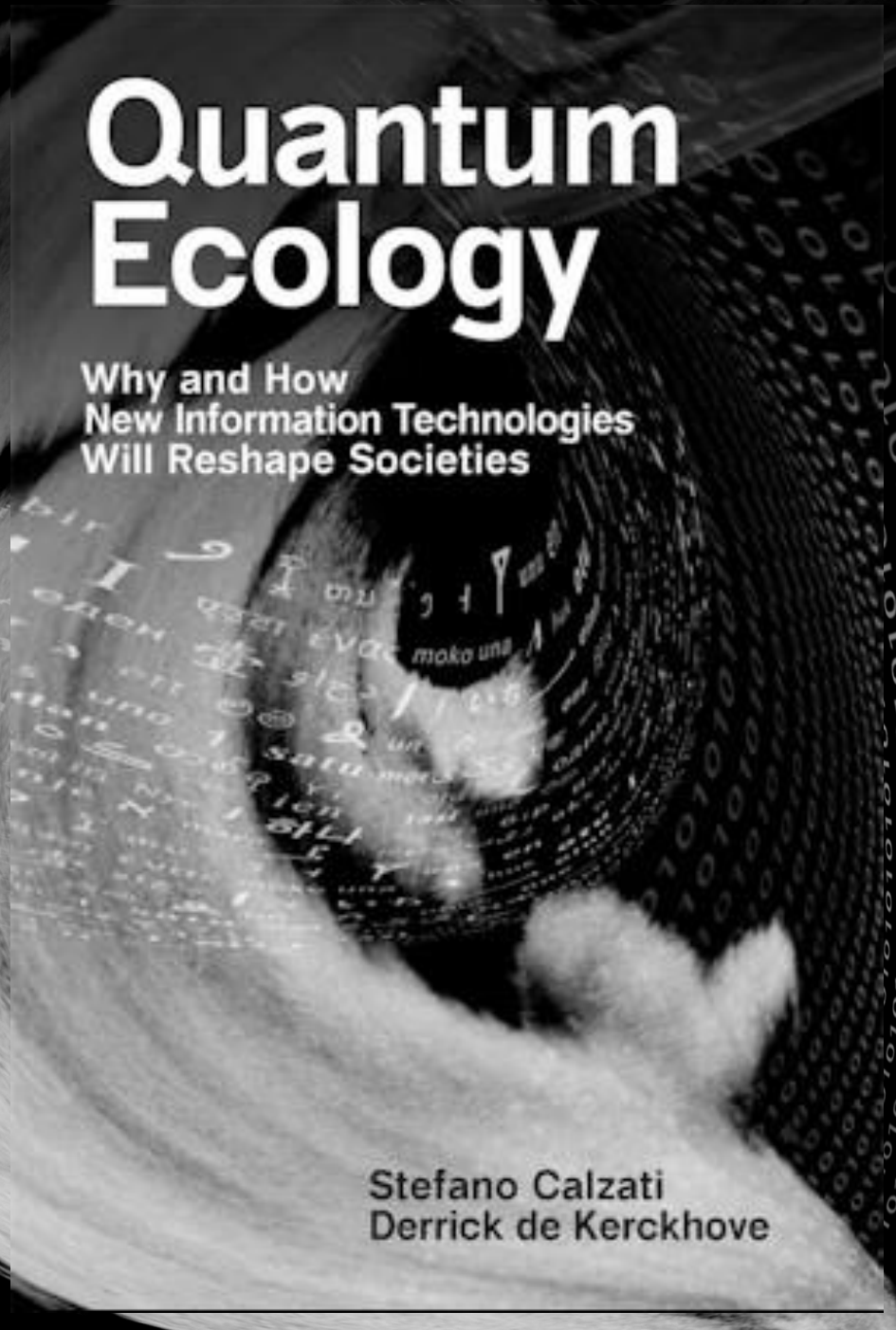
→empirical exploration of geopolitical and commercial barriers and enablers to agreed principles and mechanisms across scales

Thank you

https://stefanocalzati.com

Digital Society Topical Collection

Untangling the Quantum Ecology:
Charting the Impact of Quantum Theory and Quantum Technologies on Technoscience and the Digital Transformation



(Mi Lin, book cover's artist, Milandia 瀰瀾之域)