Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Co-evolution of Policy Knowledge and Global Governance Regime Complexes through a Complexity Theory Lens: Evidence from Global Water Governance

Dewan AN

dewan.an@sicnu.edu.cn

Sichuan Normal University

Research Article

Keywords: International Regime Complex, Complex Adaptive System, Policy Knowledge, Reflexive Emergence, Self-Organization, Global Water Governance

Posted Date: November 26th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11777195/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

The existing literature predominantly conceptualizes policy knowledge as a cognitive resource possessed by discrete actors or institutions, premised on the assumption that such knowledge—through its grasp of scientific laws—enables the attainment of specific policy outcomes. Within this framing, policy knowledge is an exogenous factor that reinforces coordination within regime complexes, thereby advancing policy integration or policy coherence. This article reconceptualizes international regime complexes as adaptive social systems and integrates the theoretical conceptions of 'reflexive emergence' and 'self-organization'. Drawing on an empirical case study of the United Nations water governance regime complex, this study demonstrates that policy knowledge constitutes an emergent property arising from interactive dynamics within the governance system. In turn, this policy knowledge, as 'reflexive emergence', operates as an 'invisible hand' that propels the self-organization of global water regime complexes. By deploying complexity theory, this article constructs an analytical framework for interrogating institutional complexity in global governance. This framework transcends the constraints of linear causal analysis by synthesizing agency and structure, while establishing a framework with predictive capacity. Consequently, it moves beyond the restrictive treatment of complex adaptive systems theory as a mere metaphor employed for descriptive analyses in international relations studies.

1. Introduction

Since 1945 the global governance system has been profoundly transformed. The number of international regimes has grown continuously, sharply raising institutional density and producing ever more serious rule overlap and normative conflict (Alter, 2022; Alter & Raustiala, 2018). Since the 2008 global financial crisis, 'right populism' and 'backlash politics', with shifts in the distribution of power, have intensified geopolitical competition and eroded the consensual foundations of the liberal international order; many regimes have steadily lost epistemic authority, their operation stalled or hollowed out, and the future of global governance has grown darker (Ikenberry, 2018; Ella & Press-Barnathan, 2025). Scholarship has responded with numerous inquiries into how global governance regimes evolve (Eilstrup-Sangiovanni, 2023).

Within these inquiries scholars have noted an affinity between policy knowledge and the evolution of governance regimes (Gilardi & Radaelli, 2012). Global governance denotes the coordination of collective action by states, international regimes and non-governmental organizations in institutionalized spaces of interaction—coordination that requires knowledge to shape governance (Glückler et al., 2020). In the present volatile political economy the evolution of regime complexes is neither mere institutional proliferation nor a passive by-product of power bargaining; it is embedded in the production of, and competition over, policy knowledge. Examining that relationship is therefore essential to understanding current practice, anticipating future trajectories and renewing theory.

The most influential theory of how policy knowledge drives the evolution of the governance system is Emanuel Adler's cognitive evolution. He defines it as 'an evolutionary collective-learning process that

explains how communities of practice establish themselves, how their background knowledge diffuses and becomes institutionalized, how their members' expectations and dispositions become preferentially selected, and how social structure spreads' (Adler, 2008, p.202). Its core claim is that change in international relations can be explained by the evolution of collective cognition, and it stresses the role of epistemic communities and communities of practice in collective learning, a process spanning innovation, selection, diffusion and institutionalization. Selection is political: ideas are retained because they serve the interests of power holders and are then endowed with authority through institutional design (Adler, 2004, pp. 66–72).

Peter Haas shows that in the scientifically uncertain domains of global environmental governance, epistemic communities of scientists identify problems and propose causal models; knowledge is diffused and tested through interaction within communities of practice and, after 'variation' and 'selection', consolidates into new policy knowledge and norms—a process of collective learning (Haas, 2021). Yu Bowen likewise finds that the Kyoto impasse prompted reflection by subnational and non-state actors and generated new practices, yet insists that social selection by power is decisive: innovative knowledge becomes normative only if it demonstrates performance and secures political support, or at least avoids the constraints of conservative forces. "Innovative practices are also often interwoven with considerations of material interest and power. Market-based carbon trading, carbon neutrality and carbon labelling, for instance, all carry economic benefits for market actors" (Yu, 2019, p. 123).

These theories nonetheless betray deficiencies when applied to the evolution of regime complexes—deficiencies rooted in their premises about where knowledge comes from and how knowledge and institutions interact. Three limitations stand out.

First, knowledge is treated as an external, given driver. In the mainstream narrative of cognitive evolution, knowledge is an entity held by individuals or epistemic communities and acting as an exogenous force on institutional evolution. Scott Cook and colleagues call this the 'epistemology of possession', because it treats knowledge as a thing detached from context, produced by a particular group and injected into policy-making (Cook & Brown, 1999, p. 381). Learning is thereby portrayed as a disembodied process, or as a stylized ideal of scientific method (De Búrca et al., 2014, p. 478). Such premises cannot explain why, in regime complexes long mired in deadlock, it is precisely the consensual understandings that no external expert community designed—but that crystallized through repeated friction in practice—that reshaped the logic of inter-regime interaction. Knowledge may be endogenous; how it emerges from within remains unanswered.

Second, the dynamics are unidirectional and outcome-oriented. Studies of cognitive evolution and regime complexes treat evolution as movement toward 'policy coordination' or 'ordering': consensual knowledge builds cooperation among conflicting regimes and culminates in policy coherence (Morin & Orsini, 2014, p. 304; Eilstrup-Sangiovanni, 2022). The chain of innovation, diffusion, selection and continuity is outcome-oriented—knowledge matters because it grasps causal relations, so that compliance yields recognized performance (Adler & Haas, 1992, p. 373). Adler's 'knowledge-based

authority', which needs material power, deontic power and performativity to pass social selection, likewise confirms that institutionalization depends on satisfying the needs of power (Adler, 2019, p. 236; Yu, 2019, p. 115). This narrative of progress from disorder to order obscures non-directional trajectories such as escalating conflict or boundary reorganization and, more importantly, reduces the force of knowledge to the results it delivers rather than to its constitutive role in shaping actors' expectations and actions (Adler et al., 2024, p. 3).

Third, the system is conceived statically and causality linearly. Although Mette Eilstrup-Sangiovanni and others include deliberate restructuring and "spontaneous adaptation" among the drivers of evolution, and concede that systems may generate order through "self-organization," their frameworks still treat global governance as relatively static and rely on actor-centred or structure-centred linear analysis (Eilstrup-Sangiovanni, 2022, p. 294). Even where spontaneous adaptation is invoked, analysis rarely moves beyond describing positive feedback and never models knowledge and institutions as continuously co-evolving (Koenig-Archibugi, 2011; Gehring & Faude, 2014). How knowledge, without centralized coordination, co-evolves with the complex as an internal emergence remains a 'black box' (Esguerra, 2024) that merits further inquiry.

These deficiencies point to a gap: if knowledge is not externally given but endogenous to regime complexes, how is it formed, and how does it co-evolve with the complexes? Answering this requires an ontological and methodological break. This article treats the global governance regime complex as an open adaptive social system comprising component regimes together with the formal institutions and informal mechanisms that coordinate relations among them. Its core claim is that policy knowledge is the 'reflexive emergence' of the regime complex—an endogenous product rather than an injected entity, at once a result of evolution and a non-material factor reshaping inter-regime relations and boundaries. The aim is to build, on the basis of complexity theory, a dynamic framework showing how such knowledge is formed and how it co-evolves with the complex.

The article makes three contributions. Conceptually, it redefines policy knowledge from external driver into internal 'emergence': knowledge is consensual understanding generated through repeated friction, adjustment and reflection among actors inside the system, and it constitutes their expectations and actions rather than merely aligning them. With respect to measurement, it abandons directional outcomes such as 'policy coordination' or 'ordering' and takes relational change among component regimes—from no relation to competition or cooperation, from cooperation to conflict—as a neutral criterion that accommodates non-directional evolution and allows boundaries to shift through issue-linkage, escaping the confinement of complexes to a single issue area. Analytically, it builds a dynamic framework of co-evolution: reflexive policy knowledge is a normative social force, an 'invisible hand' driving systemic evolution, whose indirect coordinating work is traced, through methodological innovation, in the case study of global water governance regime complex.

2. Literature Review: Knowledge and Regimes (Complexes) in Global Governance

Knowledge refers to human understanding of the world within a given socio-historical setting. Any policy contains three elements: problem, goal and instrument. Goals derive from cognition of the nature of the policy problem, and goals in turn determine the instruments deployed (Bressers & Kuks, 2013). Policy knowledge comprises technical expertise and normative belief: the technical component specifies the causal relations that generate and resolve problems and supplies practical solutions, while the normative component confers moral value and justifies action (Stoeva, 2010, pp. 3–6). It thus includes causal models and data about how the world works as well as the frameworks that define what counts as a legitimate solution.

How people understand themselves and the world differs across cultures, changes over time and is shaped by shifting institutional environments and social roles. The production of knowledge, and the controversies surrounding it, therefore shape world politics (Bliesemann de Guevara et al., 2025). The literature on policy knowledge in global governance is extensive, and Christian Bueger and others have surveyed it systematically (Bueger, 2014; Heazle et al., 2016; Allan, 2018). They agree that it falls into three successive generations.

2.1 Three Generations of Research on Policy Knowledge in Global Governance

The first generation examined how scientists and technical experts grounded in scientific rationality produce technical expertise and how it affects international policy-making. Science and politics were treated as two very different social fields: experts supply objective, independent knowledge, conflict between them is absent, and politicians readily acknowledge the authority of scientific consensus; governments must not interfere with the independence of experts, and experts must not engage in advocacy (Heazle et al., 2016).

The second generation rejected the notion that science occupies a privileged site of knowledge production and turned to policy knowledge generated in different fields. It held that the separation of expert knowledge from political authority is largely at odds with reality: the authority of all knowledge is constructed (Bueger, 2014, p. 47). It therefore attended to expertise outside science and technology and to the fusion of scientific with other knowledge, such as indigenous knowledge, and shifted from the influence of experts to how epistemic structures acquire authority. Linking knowledge production to power, it stressed the contingency of all knowledge and abandoned the exceptionality of science. It defined knowledge as a shared textual structure in which language produces international society and defines its problems, and described the ‘episteme’ as the background knowledge, discourse and practice through which people organize the world, constituting social reality and the structures of meaning in international politics (Bueger, 2014, pp. 45–46).

The third generation comprises empirical studies of how an episteme is produced. In dialogue with the post-Kuhnian sociology of science, it moved the unit of analysis from ‘actors’ and ‘discourse’ to ‘practice’, restoring agency by centring the practice of the ‘episteme’ rather than actors’ causal influence. The

concept of practice also draws attention to the material dimension of knowledge production—bodily movement, behaviour and the artefacts in which knowledge is inscribed. The question becomes through which practices authoritative expertise is produced.

In sum, the first generation studied scientists as independent actors in world politics and their causal effects; the second turned to language, reason and meaning; the third focuses on the practice of expertise and how those practices are rooted in particular historical contexts and material arrangements (Bliesemann de Guevara & Kostić, 2017; Berling & Bueger, 2016). The first generation assumed that expertise serves the common interest and brings a better future, implying a narrative of science as progress; the second and third abandoned this premise, which allowed critical analysis to expose the 'dark side' of expertise: the intimacy of knowledge and power, and the ways expertise shapes available policy options so as to preserve power relations, obstruct emancipation or marginalize the powerless (Bueger, 2014, p. 51; Vadrot, 2017).

These perspectives have shaped research on the production and diffusion of policy knowledge, setting different foci as theoretical lenses have shifted: who participates in producing policy knowledge and with what effect; the processes and instruments through which knowledge is generated and validated; and the institutions on which the stabilization and diffusion of knowledge depend (Bueger, 2015, p. 15).

First, a large body of work explains how scientific bodies and technical experts—purely epistemic authorities—shape policy-making within a given regime, proposing a supply model in which expert knowledge becomes an important source of the authority of international organizations (Littoz-Monnet, 2017a). The concept usually invoked is the epistemic community: a transmission belt of like-minded scientists whose potential influence grows with the autonomy of science from politics (Carayannis et al., 2012, p. 144). These studies concern the production and use of knowledge by a single organization within a complex, and a large literature therefore analyses international organizations as producers, diffusers and users of policy knowledge.[1] Research finds that expertise is used instrumentally to adjust policy outputs, symbolically to defend epistemic authority, strategically to justify jurisdiction over new domains, or as a means of depoliticizing contested issues (Cannon, 2017, p. 130).

Second, research on the non-linear relationship between politics and knowledge in the decision-making of international organizations proposes a 'co-production' model. This model typically requires institutions that coordinate authority across two social fields, 'science' and 'politics', known as 'boundary organizations' (Orsini, 2017; Compagnon & Bernstein, 2017). Michael Zürn calls such an architecture 'politically assigned epistemic authorities': transnational organizations or international bodies that take no binding decisions but are empowered to render interpretations, often highly consequential ones (Zürn, 2018). This architecture confers on epistemic authority a politically recognized status, and its role in contemporary global governance is rising markedly (Zürn, 2017).

Scholars have also introduced boundary organizations into the regime complex as an institutional form through which policy knowledge, and thereby the complex, is coordinated: they are defined by their creation and diffusion of shared knowledge regarded as credible, legitimate and important to each

element regime, and by their ‘bridging’ capacity, held to strengthen regime complex governance and management (Morin et al., 2017). To improve the coordination of knowledge production, scholars have even proposed “boundary chains”—linking complementary boundary organizations in order to cooperate, share costs and pool resources (Kirchhoff et al., 2015).

Finally, influenced by the third generation, scholars examine ‘epistemic infrastructure’: the combination of materials, practices and meanings, including interconnected structures of knowledge (Bandola-Gill et al., 2022, p. 6). The notion of the ‘laboratory’ treats regimes and organizations as sites within epistemic infrastructure and examines how epistemic practices construct ‘epistemic objects’ by combining elements, transforming one another and representing objects (Bueger, 2015). To address the production and validation of knowledge, Annabelle Littoz-Monnet and others propose ‘methods regimes’: socio-material arrangements that determine which methods count as ‘correct’, and are therefore central to evidence-based policy-making (Littoz-Monnet & Uribe, 2023).

2.2 Policy Knowledge as Emergence: Exploring the Co-evolution of Policy Knowledge and Regime Complexes

Overall, existing scholarship attends either to the production and use of policy knowledge by a single organization, or to knowledge-production networks among two or more organizations within a complex. Although the third generation addresses knowledge production in complexes, global problems are treated as given, as existing outside policy-makers and experts, who resolve them with the knowledge and instruments at hand. Policy knowledge is thus a substantial entity grounded in scientific truth and independent of time, place and social conditions (Littoz-Monnet, 2025).

The three generations hold that epistemic practices supported by epistemic communities, boundary organizations and infrastructures diffuse consensual knowledge widely across a complex—a linear causal analysis. Yet such work adopts a ‘spotlight’ strategy, observing only parts of the complex, like the blind men touching the elephant (Alter, 2020, p. 416). Even where intra-complex interaction is studied, only mechanical links among some regimes are captured (Henning & Pratt, 2023, p. 2182) and only formal coordinating institutions such as the Intergovernmental Panel on Climate Change are visible, not the ‘invisible hand’ within the system (Alter, 2020, p. 416). The networks producing knowledge, their institutional environment and the reach of knowledge across the complex are consequently neglected.

Moreover, policy knowledge is assumed to be external, and evolution is reduced to one-way convergence. Although the three generations note that knowledge serves as a tool of regime competition, they stress its coordinating function: knowledge promotes coordination and delivers policy integration or coherence. Policy integration aims at a situation in which decisions in different domains mutually advance one another’s objectives, generating synergies that deliver the desired outcomes (Bolognesi et al., 2021; Howlett, 2019). Policy coherence concerns how the dilemma of conflicting national policies is resolved: knowledge produces consensus on how the world should be governed, through competition aimed at resolving epistemic disagreement, with coherence as the terminal objective (Morin & Orsini, 2014, p. 304). For governments, coherence has a procedural dimension,

coordination among departments, and a substantive one, complementarity among policies; over time decisions become more coherent and the complex denser. These are mutual co-adjustments: negotiation drives regime evolution, and the complex shapes national decisions (Morin & Orsini, 2013).

Although this literature addresses the co-evolution of states with the complex, knowledge—especially expert consensus—is treated as an 'objective framework' outside institutional friction. The problem of a complex is incoherence caused by fragmentation, and knowledge supplies the adhesive. Epistemic community theory holds that actors adjust beliefs toward truth-clarifying knowledge, or that through socialization they internalize knowledge as a norm of action, shifting from a logic of consequences to a logic of appropriateness. The limitation is that, while these accounts show knowledge promoting the ordering of the system toward a policy outcome, their view of evolution is simplistic: they miss that evolution alternates between order and disorder, and that knowledge is bound up with both. They cannot explain virtuous or vicious cycles—systems becoming more complex and efficient, or simpler and less effective—through institutional integration and loosening, regime creation and decay.

This article is instead process-centred and does not claim that policy knowledge necessarily produces desirable outcomes; it asks how knowledge and complex co-evolve (Diduck, 2010). Knowledge becomes an endogenous variable rather than an exogenous instrument, evolution is two-way, and the criterion shifts from 'policy coherence' to 'adaptiveness and innovation.' Two directions are examined: how fragmentation generates knowledge innovation—when several institutions claim jurisdiction over one issue, no framework prevails uncontested, and this cognitive plurality is not a failure of governance but a structural precondition of innovation; and how emergent knowledge acts back on the institutional system, redrawing boundaries and reconfiguring relations.

This article announces a fourth generation of research on policy knowledge in international relations. Regime complexes are complex adaptive systems; in policy learning the emergence of knowledge promotes self-organization, so knowledge and complex co-evolve. Policy knowledge is the 'emergence of consensus' that becomes structured within the complex through a decentralized, self-organizing process of convergence—not fragmented 'knowledge claims held by someone or some institution' but 'consensus with structural binding force.' This addresses questions left open by earlier generations: within a complex hosting several epistemic communities, why does one prevail? Why does knowledge sometimes compete and sometimes converge? How do boundary organizations come into being, who promotes them, and how are their considerable costs overcome (Briley et al., 2015)? Must convergence proceed through boundary organizations or chains that bridge actors holding different claims?

3. Theoretical Framework: Knowledge as 'Reflexive Emergence' and the Self-organization of the Global Governance System

Some scholars have pointed to the role of knowledge in the evolution of regime complexes: knowledge is a key driver of coordination, and relations among regimes change along with it (Pahl-Wostl et al., 2007, p. 30). That role nonetheless remains insufficiently analysed. The following section therefore argues,

from the standpoint of complexity theory, that policy knowledge is the ‘reflexive emergence’ of the regime complex.

3.1 ‘Reflexive Emergence’ in Complex Social Systems

Complexity theory developed in the natural sciences and was gradually introduced into social science (Kavalski, 2007, p. 438). Ilya Prigogine’s work of 1977 on dissipative structures carried a framework previously confined to physical systems into biology and later supplied a philosophical basis for analysing social systems (Nicolis & Prigogine, 1977; Anzola et al., 2017). As complexity science advanced, researchers noted important differences between natural and social systems, even though all are complex. Physical systems tend toward equilibrium, a state characterized by maximum entropy, and notions of organization, wholeness, teleology and differentiation are of little use to physicists; biological and social systems, by contrast, are non-equilibrium (Cîndea, 2006).

Complexity science is generally taken to explain how, absent central control, large numbers of individuals interacting according to simple rules self-organize into macro patterns. In the social world, emergence carries an additional meaning: beyond autonomous interaction producing macro patterns, it involves active adaptation to the environment. In natural systems the emergent pattern is identified by an external observer—physical systems do not ‘cognize’ their own patterns and adjust accordingly; in the social world actors possess autonomous cognition, and social systems embed a loop of self-observation and self-adjustment (Goldspink & Kay, 2010, p. 47). Invisible interconnections among components—symbols, meanings and intersubjectivity—are crucial to interaction (Sawyer, 2005, p. 26). Emergence in social systems is thus autonomous interaction, without central control, whereby local and simple rules generate, through iteration and non-linear feedback, ordered and adaptive macro structures (Robiglio et al., 2025; MacGregor et al., 2020). Melanie Mitchell defines a complex adaptive system as one ‘in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information processing, and adaptation via learning or evolution’ (Mitchell, 2009, p. 13).

Chris Goldspink and colleagues contrast nonreflexive with reflexive emergence (Goldspink & Kay, 2007). The former is emergence in natural systems, without self-consciousness; the latter is emergence in social systems whose subjects possess self-consciousness and language, so that agents notice emergent patterns and use language to distinguish and discuss them. Reflexive emergence is also called ‘second order emergence’: when agents become aware that emergence is occurring, as in societies, clubs, formal organizations, institutions and so on, these facts further alter the rules of interaction between him/herself and other agents (Wagner, 2016, p. 102). Its core feature is that actors can reflect on their environment and their own practice, and can therefore deliberately change their behaviour and rules of interaction (Goldspink & Kay, 2007; de Haan, 2006, p. 296).

3.2 Policy Knowledge as “Reflexive Emergence” in Global Governance

Defining policy knowledge as reflexive emergence requires moving beyond the linear view of how external knowledge causes systemic change, and seeing co-evolution through complexity: autonomous interaction within the system produces self-organization, a change neither planned nor imposed by central control (Teisman et al., 2009, p. 12). Giddens's theory of the duality of structure holds that structure is both medium and outcome of practice: social structure—rules and resources—is not a rigid framework external to action but is repeatedly reproduced, and may be altered, as actors draw upon it (Giddens, 1984). The notion of co-evolution in governance advanced by Kristof Van Assche and colleagues is highly congruent with this (Van Assche et al., 2022b, p. 8).

Van Assche and colleagues distinguish co-evolutionary approaches from classic approaches such as policy diffusion and transfer, the learning organization and institutional design (Van Assche et al., 2022b, pp. 8–12). Literature on how organizations use knowledge typically assumes that knowledge acquired through learning always produces good results—the more knowledge, the better—and that learning can be designed, so that integrating bodies of knowledge yields useful insights, objectives and solutions (Van Assche et al., 2022b, p. 10). These approaches treat policy knowledge as an exogenous factor and as an entity held by an institution or individual and transmitted among epistemic communities through social learning, so that knowledge travels across regimes, achieves cognitive convergence and integrates the system (Van Assche et al., 2022a, p. 1212).

The co-evolutionary approach stresses that knowledge arises from interactive processes within the system—that it is endogenous—and that knowledge and governance iterate and evolve through recursive interaction, with reflexivity as the core driver. First, the system must be studied as a whole: it is not the sum of its parts, and its operation is non-linear. Second, the attributes of components are insufficient; the interactions among them must be studied. These relations are intangible yet crucial, dynamic and non-linear, so outcomes are often unpredictable; but because they are emergent, products of self-organization, they afford some insight into the system's evolution (Teisman et al., 2009, pp. 4–5).

The core of reflexive emergence is the co-evolutionary relationship between knowledge and complex. In social systems, ‘agents have an internal model of their environment that enables them to move from perception via the cognitive function to action via the manipulative function in pursuit of their goal,’ which allows agents to assert that ‘If I perceive state A (cognitive function) and take action X (manipulative function) then state B will result, bringing me closer to (or farther from) my goal G’. (Beinhocker, 2013, pp. 331–332). The behaviour of cognitively capable subjects rests not only on perception of the world but on internal beliefs and goals and on expectations about the results of action. To accomplish tasks, subjects must take account of others: goals often cannot be achieved without cooperation, and a plan involves requests, expectations about assent and about others' capacity to comply (Sawyer, 2005, p. 173). Reflexive policy knowledge questions governance itself—the concepts, practices and institutions through which it operates—and envisages alternatives, reshaping existing practice; this is the foundation of reflexive governance (Voß & Kemp, 2006; McNutt & Rayner, 2018).

‘Emergent’ knowledge differs from ordinary information: actors do not only act but look back upon their actions, assumptions and results, and distil an understanding capable of changing the structure of their system. Reflexive emergent policy knowledge is a reflexive construction: it arises from interaction among agents and in turn steers and reshapes that interaction, accelerating the emergence of new structures (Glückler et al., 2020, p. 12). Knowledge co-evolves with the complex and its environment; mutual dependence and positive feedback between them constitute a recursive dynamic in which effects become causes (Rotmans & Loorbach, 2009, p. 186). Reflexive emergence means that policy knowledge is neither pre-existing, exogenous nor centrally designed; its generation is reflexive, in that actors consciously monitor, contest and revise their knowledge, and the knowledge produced shapes subsequent interaction in a self-reinforcing loop. This loop explains why emergence in social systems is faster than in biological ones: agents do not merely adapt but continuously accelerate the reorganization of structures (Wagner, 2016, p. 103).

If knowledge and the governance system co-evolve, how can a useful framework be built on such causal circularity? They are not simply mutually causal but stand in logical relations across time and levels. It is therefore necessary to specify through what mechanisms knowledge emerges, and how it then promotes self-organization.

Scott Cook and colleagues help explain how policy emerges as reflexive emergence. They distinguish two forms of cognitive activity—*knowledge* as possession and *knowing* as practice—and stress their interaction: new knowledge is created in the interplay between the two. When people use existing knowledge to engage in knowing, the insights generated may break through its boundaries and produce genuinely novel things; this ‘generative dance’ is the source of organizational innovation. Knowing is dynamic, concrete and relational; in its interactive character the world shapes our behaviour by demanding our respect—“knowing is using knowledge as a tool to engage with the world and respecting the world” (Cook & Brown, 1999, pp. 381–387). Subjects do not unilaterally ‘frame’ the world; in practice they remain open to feedback, allowing it to question, revise or overturn their frameworks.

Multiple-loop learning theory captures the role of reflexive emergent knowledge in the self-organizing transformation of governance systems (Pahl-Wostl, 2009, p. 359). Single-loop learning is not reflexive emergence: it operates the world with existing knowledge, optimizing strategies within an established framework and never questioning goals and premises. Absent the critical reconstruction of double- and triple-loop learning, policy knowledge is only efficiency optimization; through complete multiple-loop learning the aim is not to ‘discover’ truth but to achieve the co-evolution of knowledge and governance.

Informal networks linked to formal policy networks or processes are important for completing triple-loop learning (Pahl-Wostl, 2015, pp. 167–168). ‘Interaction in formal policy cycles is largely confined to single-loop learning. Informal learning processes are necessary to support double- and even triple-loop learning’ (Pahl-Wostl, 2009, p. 361). The ‘niches’ of a complex—informal policy learning networks—promote transformation through policy learning and knowledge innovation, by generating radical and novel ideas (van Mierlo & Beers, 2020, p. 257; Ingram, 2018).

Why do informal networks facilitate triple-loop learning? The structure of a complex is emergent from autonomous interaction; couplings among actors, among the types of knowledge they hold, and between actors and knowledge affect what can be learned. Human beings display confirmation bias, and so do organizations. In a governance system particular forms of knowledge and rules of interaction are entrenched, affecting openness to alternatives and hence learning. Because complexity is excessive, no system can see fully into itself; coupling events loosely with deeper reflection, facilitated by outsiders able to engage in second-order observation, is therefore helpful (Van Assche et al., 2022b, pp. 15–18). Reflexive learning is strengthened where the system has multiple sites of observation and tolerates criticism (Van Assche et al., 2022b, p. 13).

How, then, does reflexive emergent knowledge drive self-organization? The unpredictability of learning and its distribution across time and space make it difficult to channel learning into a particular process, site, group or perspective (Dunlop & Radaelli, 2018). Learning takes different forms at different levels: people learn, organizations learn and systems learn, yet learning at one level does not transfer to another. Individuals may learn while their organizations learn nothing (Van Assche et al., 2022a, p. 1214). As the product of triple-loop learning, however, reflexive emergent knowledge resets the system's goals, rules and framework of action, changing the interaction patterns of all participants (Van Assche et al., 2022a, pp. 1211–1225). Sustained interaction can produce learning, or at least more adequate responses to problems and opportunities, of which actors may not be aware (Van Assche et al., 2022a, p. 1214). Actors may be dispersed, and emergent knowledge can induce “nested” structures among them (Teisman et al., 2009, p. 6). Social learning is a continuous, adaptive process of knowledge creation, promoted by interaction through critical reflection and the synthesis of multiple knowledge types, which expands from the individual level until it transforms social structures such as mandates, policies and norms (McCarthy et al., 2011). Emergent knowledge, as social structure, means that the norms, rules and principles of knowledge construction do not merely make expectations and actions converge, nor must they satisfy some outcome; knowledge itself constitutes those expectations and actions (Krasner, 1983; Adler et al., 2024, p. 3).

Reflexive emergent knowledge acts as an adhesive among competing or dispersed regimes, promoting self-organization indirectly. Self-organization here does not mean an externally observed macro pattern but refers to actors at different nodes sharing enough policy knowledge to reach basic agreement on the problems to be solved and on effective solutions, thereby coordinating behaviour: states and others comply with regime rules even without strong enforcement, and this coordination adjusts the boundaries of the complex.

4. Case Study: IWRM and the Evolution of the UN Water Governance Regime Complex

This section examines how Integrated Water Resources Management (IWRM) operates as reflexive emergent policy knowledge in the international water governance regime complex, and how it produced

the self-organization of the components of global water governance—specifically, the UN specialized agencies.

In the early twentieth century water governance was practised locally and regionally, since water problems were largely local. As their scope and complexity grew, global coordination became necessary (Cooley et al., 2014, pp. 15–16). Yet the UN system created after 1945 established no dedicated organization or regime for water: its specialized agencies each held a separate mandate—WHO attending to drinking water and sanitation, FAO to irrigation, WMO to the water cycle, UNESCO to hydrological science, and the World Bank to financing large infrastructure (United Nations, 1979). This functionalist design raised technical efficiency but created a vacuum in horizontal coordination: water was treated as a cross-cutting issue, embedded as a secondary item in many agencies' mandates.

Global water governance is a regime complex full of contradictions. Each agency maintains its own databases and assessment methods: FAO and WHO may separately survey rural water supply in the same country and produce incompatible datasets. At the national level, a developing country may host a WHO drinking-water programme, an FAO irrigation project, a World Bank dam loan and UNESCO training, which conflict in allocation priorities and technical standards. The recipient government must deal with several agencies and integrate their advice itself—an externalization of inter-agency coordination that sharply raises administrative costs.

In the international epistemic debate over IWRM, the Dublin Principles adopted at the 1992 International Conference on Water and the Environment marked a turning point (ICWE, 1992). They constituted a new policy paradigm built on knowledge formed through reflection on existing practice and institutional context, integrating environmental, gender, economic and participatory considerations (Bolding & Alba, 2016, pp. 672–674). Water resources management hosts many normative approaches setting out how policy-making should be organized; IWRM is one of the important ones (van Buuren, 2013). Once IWRM knowledge had taken shape, several organizations adjusted their policies within a short period, prompting self-organization of the complex.

4.1 'Reflexive Emergence' in Informal Networks of Water Policy Knowledge: IWRM as Policy Knowledge

Tracing the origins of the concept, the literature usually points to the 1992 Dublin conference or the 1977 UN Water Conference at Mar del Plata (Boinet et al., 2024) or the period after the founding of the Global Water Partnership in 1996, though some would place it earlier (García, 2008, p. 24; Snellen & Schrevel, 2004). Asit Biswas traces its development to the 1950s (Biswas, 2004b). Others reach further back: Spain may have been the first to manage water on a river-basin basis, establishing basin confederations in 1926; later decades saw serious attempts elsewhere—the Tennessee Valley Authority offered an early prototype in the 1940s, and in 1960 the German Land of Hesse adopted an Integrated Water Resources Management Plan based on a multidisciplinary approach (Rahaman & Varis, 2005).

Scholars disagree about when IWRM knowledge originated, but agree that the transition from epistemic discussion to a mainstream paradigm accepted by organizations and governments was accomplished through principles adopted at the UN level. As Ken Conca observes, 'by the late 1980s integrated water resources management had become an established concept in some core journals and in meetings of water policy experts, but it had not yet become the central framework for discussing water issues' (Conca, 2006, p. 138).

In this transformation, informal policy learning networks initiated by water think tanks played a key role. The seminars convened by the Danish Water Quality Institute acted as such a network and gave important impetus to IWRM becoming a mainstream paradigm, a shift largely completed during the 1990s. This section traces the formation of that network, the reflexive emergence of the knowledge it produced, and the way it promoted the self-organization of the UN water regime complex.

In the 1970s the United Nations convened high-level conferences on specific issues in order to discuss global problems and devise strategies—environment, population, food, women, human settlements, water, desertification, new and renewable energy—issues too complex for any single state (Biswas, 2004a). Concern for safe drinking water and adequate sanitation was articulated at the 1977 UN Water Conference in Mar del Plata; on its recommendation, the General Assembly declared '1981–1990 the International Drinking Water Supply and Sanitation Decade', focusing attention on those without access (United Nations, 1990; Neto & Tropp, 2000; Biswas & Tortajada, 2023). The 1977 conference is regarded as the beginning of global water governance discussions at the UN level.

As a global initiative, 'the Decade' concentrated narrowly on drinking water and sanitation, and the availability of water resources was taken for granted. The Danish Water Quality Institute challenged this, arguing that water had become both scarce and vulnerable in quantity and quality. With the Danish International Development Agency (DANIDA), it launched the Nordic Freshwater Initiative, whose core activity was the Copenhagen Informal Consultation on Water Resources Development and Management in November 1991. There, 45 delegates from 27 countries and UN representatives adopted the Copenhagen Declaration and Report: fresh water must be regarded as a finite and vulnerable resource, essential to sustaining life, development, health and the environment; strategies should rest on two principles—water and land resources should be managed at the lowest appropriate level, and water should be treated as an economic good whose value reflects its most valuable potential use (Clausen et al., 2024).

Immediately afterwards, in January 1992, the International Conference on Water and the Environment (ICWE) convened in Dublin. The Dublin conference was the most important global water conference since the first UN water conference at Mar del Plata, Argentina, in 1977. The Water Quality Institute, as the only non-UN member of the Dublin conference steering committee, brought the Copenhagen Declaration and its related principles onto the agenda of the ICWE, and supported DANIDA in an advisory capacity in the preparations for the UN Conference on Environment and Development (UNCED) (Clausen et al., 2024).

From 26 to 31 January 1992, 500 participants—experts nominated by one hundred governments and representatives of eighty organizations—met in Dublin. The experts judged the global supply and use of water to be in a serious condition, and the closing session adopted the Dublin Statement and conference report. Four Dublin Principles emerged, three inspired by Copenhagen: water as a finite and vulnerable resource, the participatory approach, and water as an economic good. The fourth emphasized the role of women in water resources management.

The conference was intended to frame the freshwater issue for UNCED, held in Rio de Janeiro in June 1992. Participants recommended the Dublin Statement to the world leaders assembled there, urging governments to study the proposed actions and translate them into urgent action programmes for water and sustainable development (ICWE, 1992). The Copenhagen-inspired Dublin Principles then shaped the freshwater chapter of *Agenda 21*, formally establishing the standing of IWRM (Clausen et al., 2024). These principles were elaborated in the conference conclusions, with recommendations for implementation in Chap. 18 of *Agenda 21*(United Nations, 1992).

Paragraph 18.3 of *Agenda 21* stressed the need for an integrated approach: “The widespread scarcity, gradual destruction and aggravated pollution of freshwater resources in many world regions, along with the progressive encroachment of incompatible activities, demand integrated water resources planning and management”. Paragraph 18.8 provided the definition of IWRM: “Integrated water resources management is based on the perception of water as an integral part of the ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilization. To this end, water resources have to be protected, taking into account the functioning of aquatic ecosystems and the perenniality of the resource, in order to satisfy and reconcile needs for water in human activities. In developing and using water resources, priority has to be given to the satisfaction of basic needs and the safeguarding of ecosystems. Beyond these requirements, however, water users should be charged appropriately” (United Nations, 1992, ch. 18).

At the core of IWRM lies a narrative of scarcity: it emphasizes managing demand rather than augmenting supply, takes the river basin as the basic unit, restricts water use to protect and restore ecosystems, and prioritizes economic efficiency through markets. Its principles are three: water should be managed within river basins or catchments, where it is renewable but finite and possibly scarce; because it is scarce it must be treated as a commodity; and because competition is unavoidable, participatory approaches are required within basins. Consistent with demand management, the Dublin Principles say nothing about increasing availability through infrastructure (Woodhouse & Muller, 2017).

The emergence of IWRM embodied reflection on fragmented practice. Each agency had concentrated on the “projects” of its own domain with limited coordination: before 1992 water was framed sectorally—FAO for agricultural water, WHO for sanitation, WMO for hydrological data, the World Bank for infrastructure finance—which gave each organization clear boundaries and jurisdiction. Traditional governance was highly departmentalized: supply, irrigation, flood control, hydropower and wastewater treatment belonged to different bodies with separate norms, instruments and budgets; coordination was

lacking and environmental needs neglected. Knowledge was divided into unconnected 'professional warehouses,' and practice followed simple stimulus–response rules. IWRM's advocates recognized that sectoral division produced allocation conflicts, ecological degradation and governance failure; through conferences, research documents and knowledge networks they built a paradigm grounded in the basin as basic unit, socio-economic-ecological balance and stakeholder participation—a shift from 'managing water' to 'governing water systems', from engineering optimization to social learning—superseding the Drinking Water Decade by linking water, land and environmental sustainability (Allouche, 2016, p. 419). Actors consciously changed the rules of interaction, moving from sectoral competition to cross-sectoral negotiation.

4.2 The 'Self-organization' of the UN Water Governance Regime Complex under the IWRM Framework

In 1993 relations among the UN specialized agencies in water governance changed markedly. The change was rooted in the discussions of the informal knowledge network and in the 1992 Dublin conference and Rio summit, which pushed IWRM forward as "reflexive social emergence": if water is a finite and vulnerable resource requiring integrated, cross-sectoral management, no single organization can claim exclusive jurisdiction over it.

FAO, UNDP and the World Bank each completed key policy adjustments in that year, and together they built the architecture of IWRM-based multilateral governance. At the outset each was made independently. This provides clear evidence that IWRM, as policy knowledge and paradigm, drove FAO, WHO and the World Bank to converge and ultimately produced the self-organization of the UN water governance regime complex.

In 1993 the Board of the World Bank adopted *Water Resources Management*, reflecting the consensus formed at Rio: modern management should rest on three principles. The ecological principle holds that independent sectoral management is inappropriate, the river basin should be the unit of analysis, land and water must be managed together, and more attention must go to the environment. The institutional principle holds that management works best when all stakeholders—state, private sector and civil society—participate, that women must be included, and that management should respect subsidiarity. The instrumental principle holds that water is scarce and that incentives and economic principles should be used more to improve allocation and quality (World Bank, 2004).

The new approach rested on lessons learned: an integrated framework treating water as an economic good, combined with decentralized management and supply, greater reliance on pricing and fuller stakeholder participation—consistent with the Dublin Statement and *Agenda 21* (World Bank, 1993a, p. 10). Although the document did not use the term "IWRM," let alone define it, a text box introduced the main outcomes of Dublin and Rio, including the four guiding principles (Snellen & Schrevel, 2004). The Dublin Statement called for new approaches to assessing, developing and managing freshwater, and the paper likewise advocated recognizing water as a "commodity" (World Bank, 1993b). As the new

discourse gained legitimacy, the World Bank joined with UNDP to promote the creation of the Global Water Partnership (Allouche, 2016, p. 420).

In *The State of Food and Agriculture 1993*, FAO devoted a chapter to "Water policy and agriculture," beginning to place agricultural water use within a broader IWRM framework. Since agricultural water then accounted for more than two-thirds of global freshwater withdrawals, the chapter was intended to move the sector toward considering policy options within a macro-level governance framework. FAO stated:

In recent years, water issues have been the focus of increasing international concern and debate. From 26 to 31 January 1992, the UN system sponsored the International Conference on Water and the Environment (ICWE) in Dublin, Ireland. The ICWE called for innovative approaches to the assessment, development and management of freshwater resources. In addition, the ICWE provided policy guidance for the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992. UNCED highlighted the need for water sector reforms throughout the world. In 1993, the World Bank issued a comprehensive policy paper defining its new objectives for the water sector. FAO recently established an International Action Programme on Water and Sustainable Agricultural Development. Likewise, the UNDP, WHO, UNICEF, WMO, UNESCO and UNEP are all coordinating or participating in special programmes related to water resources. Other international, national and local organizations are becoming more active in water issues (FAO, 1993).

Beyond the World Bank's 1993 policy paper *Water Resources Management*, the technical paper *A Guide to the Formulation of Water Resources Strategy*, prepared jointly by UNDP and the World Bank and published in 1994, and FAO's *Reforming Water Resources Policy: A Guide to Methods, Processes and Practices*, published in 1995, also set out procedures and methods for water policy reform and specific guidance for formulating water resources strategy. These documents, however, converged on IWRM largely separately; in order better to meet water demand and the requirements of sustainable development, UN organizations, the World Bank and national governments were obliged to conduct joint water policy reviews (World Bank et al., 1995).

In September 1994 the Subcommittee on Water Resources of the UN Administrative Committee on Coordination (ACC-SWR) asked UNDP, FAO and the World Bank to prepare jointly guidelines on water policy review and reform and on strategy formulation (World Bank et al., 1995). The agencies accordingly merged their publications; to that end FAO organized in January 1995 an Expert Consultation on Methodology for Water Policy Review and Reform, at which their policy documents were reviewed jointly. The consultation involved the three agencies, several organizations of the UN system and a number of selected countries.[2] The principal outcome was *Water Sector Policy Review and Strategy Formulation: A General Framework* (1995), which proposed a systematic two-stage review of water policy—review and adjustment of policy, followed by formulation of strategy (UN ECOSOC, 1997).

IWRM's contribution to coordinated relations operated at two levels. First, it supplied a common policy language and conceptual framework—'finite and vulnerable resource,' 'participatory management', 'the

basin as the basic unit of governance', 'the economic value of water'—that agencies could jointly invoke. Second, this shared knowledge drove deeper policy integration, most visibly in the 1995 General Framework issued jointly by UNDP, FAO and the World Bank, whose very production marked a shift from loose collaboration to deep coordination. The 1994–1995 exercise was a micro but crucial step in self-organization: without any central coordination mechanism, the agencies acted spontaneously according to the logic of IWRM knowledge. IWRM did not design the complex by command and control; by changing actors' understanding of the problem it prompted cooperation, generated new functions and consolidated the working pattern through expert networks.

5. Conclusion

Within the water governance regime complex, some component regimes stand in hierarchical relations and others do not, and evolution involves both centralized control and self-organization (Bressers & Kuks, 2013). The case shows IWRM promoting the self-organization of some component regimes. The article thus supplements a literature concentrated on how IWRM diffused after becoming an international norm, emphasizing aid agencies and transnational networks, with diffusion through coercion, cooperation and learning (Kramer & Pahl-Wostl, 2014; Allouche, 2016). That literature centres on IWRM's policy effectiveness, manifested in the tension between global consensus and local practice—rooted in the ambiguity of the concept and in the disjunction between global norms and local realities. It neglects a prior question: why did so many organizations, agencies and states accept IWRM, even where agencies imposed it through loan conditionality, and why did no competing knowledge emerge in these loose transnational networks? If diffusion is the "downstream" embedding of IWRM in national institutions and law, knowledge generation is the "upstream," and this article offers a longer story of it.

The article also invites a reconsideration of how regime complexes are defined. In 2004 Kal Raustiala and David Victor coined the term, defining a regime complex as 'a set of partially overlapping and nonhierarchical institutions governing a particular issue-area' (Raustiala & Victor, 2004) whose element regimes have functionally overlapping rules but no agreed authority relations for resolving conflicts, so that fragmentation results (Alter, 2020, pp. 416–417; Eilstrup-Sangiovanni & Westerwinter, 2022). Their later restatement added that the coexistence of rule density and such complexes constitutes international institutional complexity; their definitions confine a complex to a single issue area (Alter & Raustiala, 2018). Randall Henning defines regime complexity as 'a set of international institutions operating in a common policy issue area, together with the (formal and informal) mechanisms that coordinate them': multiple institutions in that area, formal or informal; the coordinating mechanisms among them; and a boundary that is not fixed, since issue areas may change through external events or strategic restructuring (Henning & Pratt, 2023, p. 2181). Henning drops the emphasis on hierarchy, stresses informal coordination and points to open boundaries—issue areas may expand and unrelated regimes may form a single complex, opening space for a dynamic approach. Research treating complexes as complex adaptive systems is now growing and marks an important turn (Pouliot & Thérien, 2023, p. 6).

The article attempts to break with the traditional strategy of linear causal analysis, which assumes complexes to be static, as though regimes operated according to rational design, unaffected by the changing political economy, and adopts a ‘spotlight’ strategy examining a subset of regimes. Empirically, such work investigates interaction across scopes: dyadic relationships between two regimes, multiple dyads, and broad interaction among the regimes forming a complex (Elsässer et al., 2022, p. 376). Thomas Gehring and Sebastian Oberthür define institutional interaction as a causal relationship in which one institution (the ‘source’) influences another (the ‘target’); absent such influence there is merely coexistence. Influence is unidirectional, not reciprocal (Gehring & Oberthür, 2009; Oberthür & Gehring, 2006, p. 6). This spotlight ignores the fact that a shock in one issue area reverberates in the regimes of another (Alter, 2020, p. 416). Consequently, research is either actor-driven or focused on how changes in system attributes affect governance effectiveness; agency and structure remain separate, and co-evolution cannot be displayed.

Approaching the complex as a complex adaptive system extends understanding of the dynamism of the institutional environment and explains how policy knowledge can act as an ‘invisible hand’—an informal, hidden coordinating mechanism inside the complex. Progress requires methodological innovation: research studying individual regimes in isolation risks detachment from reality, failing to study partial couplings and dynamic change (Orsini et al., 2020). The remedy is methodological relationalism, which stresses that things are not pre-existing or unconstructed: without relations there are no things. Relationalists oppose essentialism, which holds that the nature of a thing depends on what it is composed of; yet, as Waltz emphasized, for features arising from the organization of elements we need a relational and systemic approach (Donnelly, 2019, pp. 918–919).

Although some International Relations scholarship describes global governance as a complex evolving system with self-organizing capacity, the non-linear dynamics and non-equilibrium features of such systems pose methodological challenges, so that complexity theory has often served descriptively as a ‘metaphor’ and no predictive theory could be built (Bousquet & Curtis, 2011). This article applies complexity theory to institutional complexity and, building on reflexive emergence and self-organization, constructs a framework with predictive capacity: policy knowledge, as reflexive emergence, is one of the drivers of regime-complex evolution. The framework unites agency and structure, examining the co-evolution of actors and of the social action systems they compose.

The article also brings out the entanglement of knowledge and power. Policy knowledge is both a tool of power competition and of transnational coordination, and can reshape power among states. Within a part of a complex, it may follow a supply model based on independent research, or be used strategically in the interests of particular actors (Gilardi & Radaelli, 2012, pp. 156–159; Grin & Loeber, 2007). Some studies treat evolution as purposive, with knowledge serving policy integration or national coherence. By contrast, this article holds that the complex is an open system whose environment requires adjustment; actors' cognition evolves through reflection on the institutional environment and the effects of practice, and reflexive emergent knowledge represents the cognitive consensus of a particular time and place—people believe some adjustment will improve matters and are willing to adopt it. This is consistent with

‘experimental governance,’ which stresses reflective learning, solutions being improved through trial rather than imposed from above (De Búrca et al., 2014). Constrained by length, the article does not trace a longer period; but the ‘water–energy–food–climate nexus’ has recently risen as new policy knowledge, criticizing the once-dominant IWRM and possibly superseding it (Schmidt & Matthews, 2018).

Whereas evolution in biological systems requires environmental selection, cognitive evolution theory emphasizes social selection by power. Cognitive evolution combines innovation and political selection: it first creates ‘objective’ collective understandings that guide governments' interests, and new policy concepts must then command sufficient power support to negate and displace competing expectations and values (Adler, 2004, p. 72). Competing epistemic claims may coexist, but social selection acts as a filter determining which community's knowledge obtains official support and rises from marginal discourse to governance principle. Knowledge serves power; and although epistemic communities generate objective knowledge, innovation is not ‘blind’—innovators must consider whether their knowledge can be selected (Adler, 2004, p. 73). This article shows that policy knowledge, as reflexive emergence, is itself an epistemic selection capable of promoting self-organization, because within a given regime competing cognitions do not always exist: the governance system shapes collective learning and determines its content. Knowledge no longer merely satisfies the taste of power but changes power: to solve problems, actors must follow the guidance of reflexive knowledge and alter their strategies. In the water regime complex, IWRM performed the function of an adhesive within a particular space and time, rapidly promoting self-organization.

Notes

1. 1. This literature mainly examines how international organizations draw on external expertise rather than how policy knowledge is produced inside them; see Littoz-Monnet (2017b, p. 4).
2. 2. The two documents were merged by Hugh Turral of the Overseas Development Institute, London, drawing on comments from the Expert Consultation on Methodology for Water Policy Review and Reform convened by the FAO in Rome in January 1995 (World Bank et al., 1995).

Declarations

Author Contribution

Dewan AN wrote the main manuscript text and reviewed the manuscript.

References

1. Adler, E. (2004). *Communitarian international relations: The epistemic foundations of international relations*. Routledge. https://doi.org/10.4324/9780203022443
2. Adler, E. (2008). The spread of security communities: Communities of practice, self-restraint, and NATO's post–Cold War transformation. *European Journal of International Relations*, *14*(2), 195–230.

https://doi.org/10.1177/1354066108089241

3. Adler, E. (2019). *World ordering: A social theory of cognitive evolution*. Cambridge University Press.
4. Adler, E., & Haas, P. M. (1992). Conclusion: epistemic communities, world order, and the creation of a reflective research program. *International Organization*, *46*(1), 367–390. https://doi.org/10.1017/s0020818300001533
5. Adler, E., Bremberg, N., & Sondarjee, M. (2024). Communities of practice in world politics: Advancing a research agenda. *Global Studies Quarterly*, *4*(1). https://doi.org/10.1093/isagsq/ksad070
6. Allan, B. B. (2018). From subjects to objects: Knowledge in international relations theory. *European Journal of International Relations*, *24*(4), 841–864. https://doi.org/10.1177/1354066117741529
7. Allouche, J. (2016). The birth and spread of IWRM: A case study of global policy diffusion and translation. *Water Alternatives*, *9*(3), 412–433.
8. Alter, K. J. (2020). Comprehending global governance: International regime complexity vs. global constitutionalism. *Global Constitutionalism*, *9*(2), 413–423. https://doi.org/10.1017/S2045381719000418
9. Alter, K. J. (2022). The promise and perils of theorizing international regime complexity in an evolving world. *The Review of International Organizations*, *17*(2), 375–396. https://doi.org/10.1007/s11558-021-09448-8
10. Alter, K. J., & Raustiala, K. (2018). The rise of international regime complexity. *Annual Review of Law and Social Science*, *14*(1), 329–349. https://doi.org/10.1146/annurev-lawsocsci-101317-030830
11. Anzola, D., Barbrook-Johnson, P., & Cano, J. I. (2017). Self-organization and social science. *Computational and Mathematical Organization Theory*, *23*(2), 221–257. https://doi.org/10.1007/s10588-016-9224-2
12. Bandola-Gill, J., Grek, S., & Tichenor, M. (2022). The Sustainable Development Goals as epistemic infrastructures. In *Governing the Sustainable Development Goals: Quantification in global public policy*. *Palgrave Macmillan*. https://doi.org/10.1007/978-3-031-03938-6_1
13. Beinhocker, E. D. (2013). Reflexivity, complexity, and the nature of social science. *Journal of Economic Methodology*, *20*(4), 330–342.
14. Berling, T. V., & Bueger, C. (Eds.). (2016). *Security expertise: Practice, power, responsibility*. Routledge.
15. Biswas, A. K. (2004a). From Mar del Plata to Kyoto: an analysis of global water policy dialogue. *Global Environmental Change*, *14*, 81–88. https://doi.org/10.1016/j.gloenvcha.2003.11.003
16. Biswas, A. K. (2004b). Integrated water resources management: A reassessment. *Water International*, *29*(2), 248–256. https://doi.org/10.1080/02508060408691775
17. Biswas, A. K., & Tortajada, C. (2023). United Nations water conferences: reflections and expectations. *International Journal of Water Resources Development*, 39(2), 177–183. https://doi.org/10.1080/07900627.2023.2176655
18. de Bliesemann, B., & Kostić, R. (2017). Knowledge production in/about conflict and intervention: Finding 'facts', telling 'truth'. *Journal of Intervention and Statebuilding*, *11*(1), 1–20.

19. de Bliesemann, B. (2025). Introduction: Studying international politics through the lens of knowledge and expertise. In B. Bliesemann, de Guevara, et al. (Eds.), *Knowledge and expertise in international politics: A handbook*. Oxford University Press. https://doi.org/10.1093/oso/9780192871145.003.0001
20. Boinet, E., Tardieu, E., Brachet, C., & Bernard, A. (2024). Lessons from the last 30 years for future water resource management in national and transboundary basins. *Water International*, *49*(3–4), 255–266. https://doi.org/10.1080/02508060.2024.2343176
21. Bolding, A., & Alba, R. (2016). Viewpoint – IWRM and I: A reflexive travelogue of the Flows and Practices research team. *Water Alternatives*, *9*(3), 672–674.
22. Bolognesi, T., Metz, F., & Nahrath, S. (2021). Institutional complexity traps in policy integration processes: a long-term perspective on Swiss flood risk management. *Policy Sciences*, *54*(4), 911–941. https://doi.org/10.1007/s11077-021-09443-1
23. Bousquet, A., & Curtis, S. (2011). Beyond models and metaphors: complexity theory, systems thinking and international relations. *Cambridge Review of International Affairs*, *24*(1), 43–62. https://doi.org/10.1080/09557571.2011.558054
24. Bressers, H., & Kuks, S. (2013). Water governance regimes: Dimensions and dynamics. *International Journal of Water Governance*, *1*(1), 133–156. https://doi.org/10.7564/12-IJWG1
25. Briley, L., Brown, D., & Kalafatis, S. E. (2015). Overcoming barriers during the co-production of climate information for decision-making. *Climate Risk Management*, *9*, 41–49. https://doi.org/10.1016/j.crm.2015.04.004
26. Bueger, C. (2014). From expert communities to epistemic arrangements: Situating expertise in international relations. In M. Mayer, M. Carpes, & R. Knoblich (Eds.), *The global politics of science and technology*(Vol. 1). Springer. https://doi.org/10.1007/978-3-642-55007-2_2
27. Bueger, C. (2015). Making things known: Epistemic practices, the United Nations, and the translation of piracy. *International Political Sociology*, *9*(1), 1–18. https://doi.org/10.1111/ips.12073
28. Cannon, C. (2017). Modes of knowledge mobilization by/for international bureaucracies throughout international policy processes. In A. Littoz-Monnet (Ed.), *The politics of expertise in international organizations*. Routledge.
29. Carayannis, E. G., Pirzadeh, A., & Popescu, D. (2012). Epistemic communities, knowledge transfer, and institutional learning. *Institutional learning and knowledge transfer across epistemic communities*. Springer. https://doi.org/10.1007/978-1-4614-1551-0_4
30. Clausen, T. J. (2024). et.al. *The IWRM story: The start of integrated water resources management*. DHI. https://blog.dhigroup.com/the-iwrm-story/
31. Compagnon, D., & Bernstein, S. (2017). Nondemarcated spaces of knowledge-informed policy making: How useful is the concept of boundary organization in IR? *Review of Policy Research*, *34*(6), 812–826. https://doi.org/10.1111/ropr.12258
32. Conca, K. (2006). *Governing water: Contentious transnational politics and global institution building*. MIT Press.

33. Cook, S. D. N., & Brown, J. S. (1999). Bridging epistemologies: The generative dance between organizational knowledge and organizational knowing. *Organization Science*, *10*(4), 381–400.
34. Cooley, H. (2014). Global water governance in the twenty-first century. In P. H. Gleick (Ed.), *The world's water*(Vol. 8, pp. 15–16). Island Press. https://doi.org/10.5822/978-1-61091-483-3_1
35. Cîndea, I. (2006). Complex systems: New conceptual tools for international relations. *Perspectives*, *26*, 46–68.
36. De Búrca, G., Keohane, R. O., & Sabel, C. (2014). Global experimentalist governance. *British Journal of Political Science*, *44*(3), 477–486. https://doi.org/10.1017/S0007123414000076
37. de Haan, J. (2006). How emergence arises. *Ecological Complexity*, *3*(4), 293–301. https://doi.org/10.1016/j.ecocom.2007.02.003
38. Diduck, A. (2010). The learning dimension of adaptive capacity: Untangling the multi-level connections. In D. Armitage, & R. Plummer (Eds.), *Adaptive capacity and environmental governance*. Springer. https://doi.org/10.1007/978-3-642-12194-4_10
39. Donnelly, J. (2019). Systems, levels, and structural theory: Waltz's theory is not a systemic theory (and why that matters for international relations today). *European Journal of International Relations*, *25*(3), 904–930. https://doi.org/10.1177/1354066118820929
40. Dunlop, C. A., & Radaelli, C. M. (2018). Policy learning and organizational capacity. In E. Ongaro, & van S. Thiel (Eds.), *The Palgrave handbook of public administration and management in Europe*. Palgrave Macmillan. https://doi.org/10.1057/978-1-137-55269-3_31
41. Eilstrup-Sangiovanni, M. (2022). Ordering global governance complexes: The evolution of the governance complex for international civil aviation. *The Review of International Organizations*, *17*(2), 293–322. https://doi.org/10.1007/s11558-020-09411-z
42. Eilstrup-Sangiovanni, M. (2023). The instability of the nuclear nonproliferation regime complex. *Review of International Political Economy*, *30*(6), 2094–2121. https://doi.org/10.1080/09692290.2023.2238732
43. Eilstrup-Sangiovanni, M., & Westerwinter, O. (2022). The global governance complexity cube: Varieties of institutional complexity in global governance. *The Review of International Organizations*, *17*(2), 233–262. https://doi.org/10.1007/s11558-021-09449-7
44. Ella, D., & Press-Barnathan, G. (2025). Complex cooptation: How regime complexity affects the stability of cooptation bargains—the case of China and the World Bank. *Contemporary Security Policy*, *46*(1), 66–97. https://doi.org/10.1080/13523260.2024.2419174
45. Elsässer, J. P., Hickmann, T., Jinnah, S., Oberthür, S., & Van de Graaf, T. (2022). Institutional interplay in global environmental governance: lessons learned and future research. *International Environmental Agreements: Politics Law and Economics*, *22*(2), 373–391. https://doi.org/10.1007/s10784-022-09569-4
46. Esguerra, A. (2024). Objects of expertise: The socio-material politics of expert knowledge in global governance. *Global Studies Quarterly*, *4*(3), ksae060. https://doi.org/10.1093/isagsq/ksae060
47. FAO. (1993). *The state of food and agriculture 1993*. Food and Agriculture Organization.

48. García, L. E. (2008). Integrated water resources management: A 'small' step for conceptualists, a giant step for practitioners. *International Journal of Water Resources Development*, *24*(1), 23–36. https://doi.org/10.1080/07900620701723141
49. Gehring, T., & Faude, B. (2014). A theory of emerging order within institutional complexes: How competition among regulatory international institutions leads to institutional adaptation and division of labor. *The Review of International Organizations*, *9*(4), 471–498.
50. Gehring, T., & Oberthür, S. (2009). The causal mechanisms of interaction between international institutions. *European Journal of International Relations*, *15*(1), 125–156. https://doi.org/10.1177/1354066108100055
51. Giddens, A. (1984). *The constitution of society: Outline of the theory of structuration*. Polity.
52. Gilardi, F., & Radaelli, C. M. (2012). Governance and learning. In D. Levi-Faur (Ed.), *The Oxford handbook of governance*. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199560530.013.0011
53. Glückler, J., Herrigel, G., & Handke, M. (2020). On the reflexive relations between knowledge, governance, and space. In J. Glückler, G. Herrigel, & M. Handke (Eds.), *Knowledge for governance*. Springer. https://doi.org/10.1007/978-3-030-47150-7_1
54. Goldspink, C., & Kay, R. (2007). Social emergence: Distinguishing reflexive and non-reflexive modes. *Emergent agents and socialities: Social and organizational aspects of intelligence* (pp. 48–55). AAAI.
55. Goldspink, C., & Kay, R. (2010). Emergence in organizations: The reflexive turn. *Emergence: Complexity and Organization*, *12*(3), 47–63.
56. Grin, J., & Loeber, A. (2007). Theories of policy learning: Agency, structure, and change. In F. Fischer, G. J. Miller, & M. S. Sidney (Eds.), *Handbook of public policy analysis* (pp. 201–219). CRC.
57. Haas, P. M. (2021). Cognitive evolution and the social construction of complexity. In P. Ish-Shalom, M. Kornprobst, & V. Pouliot (Eds.), *Theorizing world orders: Cognitive evolution and beyond* (pp. 134–168). Cambridge University Press.
58. Heazle, M., Kane, J., & Patapan, H. (2016). Good public policy: On the interaction of political and expert authority. In M. Heazle, & J. Kane (Eds.), *Policy legitimacy, science and political authority* (pp. 1–20). Routledge.
59. Henning, C. R., & Pratt, T. (2023). Hierarchy and differentiation in international regime complexes: A theoretical framework for comparative research. *Review of International Political Economy*, *30*(6), 2178–2205. https://doi.org/10.1080/09692290.2023.2259424
60. Howlett, M. (2019). Procedural policy tools and the temporal dimensions of policy design. *International Review of Public Policy*, *1*(1), 27–45. https://doi.org/10.4000/irpp.310
61. ICWE (1992). *The Dublin statement and report of the conference*. International Conference on Water and the Environment.
62. Ikenberry, G. J. (2018). The end of liberal international order? *International Affairs*, *94*(1), 7–23. https://doi.org/10.1093/ia/iix241

63. Ingram, J. (2018). Agricultural transition: Niche and regime knowledge systems' boundary dynamics. *Environmental Innovation and Societal Transitions*, *26*, 117–135. https://doi.org/10.1016/j.eist.2017.05.001
64. Kavalski, E. (2007). The fifth debate and the emergence of complex international relations theory: Notes on the application of complexity theory to the study of international life. *Cambridge Review of International Affairs*, *20*(3), 435–454.
65. Kirchhoff, C. J., Esselman, R., & Brown, D. (2015). Boundary organizations to boundary chains: Prospects for advancing climate science application. *Climate Risk Management*, *9*, 20–29. https://doi.org/10.1016/j.crm.2015.04.001
66. Koenig-Archibugi, M. (2011). Global governance. In J. Michie (Ed.), *The handbook of globalisation* (pp. 393–406). Edward Elgar.
67. Kramer, A., & Pahl-Wostl, C. (2014). The global policy network behind integrated water resources management: Is it an effective norm diffusor? *Ecology and Society*, *19*(4), 11.
68. Krasner, S. D. (Ed.). (1983). *International regimes*. Cornell University Press.
69. Littoz-Monnet, A. (2017a). Expert knowledge as a strategic resource: International bureaucrats and the shaping of bioethical standards. *International Studies Quarterly*, *61*(3), 584–595. https://doi.org/10.1093/isq/sqx016
70. Littoz-Monnet, A. (2017b). Production and uses of expertise by international bureaucracies. In A. Littoz-Monnet (Ed.), *The politics of expertise in international organizations*. Routledge.
71. Littoz-Monnet, A. (2025). Studying the assembling of expertise in global governance. In N. Mansouri, & D. R. Quiroga-Villamarín (Eds.), *Ways of seeing international organisations* (pp. 59–80). Cambridge University Press.
72. Littoz-Monnet, A., & Uribe, J. (2023). Methods regimes in global governance: The politics of Evidence-Making in global health. *International Political Sociology*, *17*(2). https://doi.org/10.1093/ips/olad005
73. MacGregor, H. E. A., Herbert-Read, J. E., & Ioannou, C. C. (2020). Information can explain the dynamics of group order in animal collective behaviour. *Nature Communications*, *11*(1). https://doi.org/10.1038/s41467-020-16578-x
74. McCarthy, D. D. P., Crandall, D. D., Whitelaw, G. S., General, Z., & Tsuji, L. J. S. (2011). A critical systems approach to social learning: Building adaptive capacity in social, ecological, epistemological (SEE) systems. *Ecology and Society*, *16*(3). https://doi.org/10.5751/es-04255-160318
75. McNutt, K., & Rayner, J. (2018). Is learning without teaching possible? The productive tension between network governance and reflexivity. *Journal of Environmental Policy & Planning*, *20*(6), 769–780. https://doi.org/10.1080/1523908x.2014.986568
76. Mitchell, M. (2009). *Complexity: A guided tour*. Oxford University Press.
77. Morin, J. F., & Orsini, A. (2013). Regime complexity and policy coherency: Introducing a co-adjustments model. *Global Governance: A Review of Multilateralism and International Organizations*,

19(1), 41–51. https://doi.org/10.1163/19426720-01901004

78. Morin, J. F., & Orsini, A. (2014). Policy coherency and regime complexes: The case of genetic resources. *Review of International Studies*, *40*(2), 303–324. https://doi.org/10.1017/S0260210513000168
79. Morin, J. F., Louafi, S., Orsini, A., & Oubenal, M. (2017). Boundary organizations in regime complexes: A social network profile of IPBES. *Journal of International Relations and Development*, *20*(3), 543–577.
80. Neto, F., & Tropp, H. (2000). Water supply and sanitation services for all: global progress during the 1990s. *Natural Resources Forum*, *24*(3), 225–235. https://doi.org/10.1111/j.1477-8947.2000.tb00946.x
81. Nicolis, G., & Prigogine, I. (1977). *Self-organization in nonequilibrium systems: From dissipative structures to order through fluctuations*. Wiley.
82. Oberthür, S., & Gehring, T. (Eds.). (2006). *Institutional interaction in global environmental governance: Synergy and conflict among international and EU policies*. MIT Press.
83. Orsini, A., et al. (2020). Forum: Complex systems and international governance. *International Studies Review*, *22*(4), 1008–1038. https://doi.org/10.1093/isr/viz005
84. Orsini, A., Louafi, S., & Morin, J. (2017). Boundary concepts for boundary work between science and technology studies and international relations: Special issue introduction. *Review of Policy Research*, *34*(6), 734–743. https://doi.org/10.1111/ropr.12273
85. Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change*, *19*(3), 354–365. https://doi.org/10.1016/j.gloenvcha.2009.06.001
86. Pahl-Wostl, C. (2015). A theory on water governance dynamics. In C. Pahl-Wostl (Ed.), *Water governance in the face of global change*. Springer.
87. Pahl-Wostl, C., Sendzimir, J., Jeffrey, P., Aerts, J., Berkamp, G., & Cross, K. (2007). Managing change toward adaptive water management through social learning. *Ecology and Society*, *12*(2). https://doi.org/10.5751/es-02147-120230
88. Pouliot, V., & Thérien, J. P. (2023). *Global policymaking: The patchwork of global governance*. Cambridge University Press.
89. Rahaman, M. M., & Varis, O. (2005). Integrated water resources management: evolution, prospects and future challenges. *Sustainability: Science Practice and Policy*, *1*(1), 15–21. https://doi.org/10.1080/15487733.2005.11907961
90. Raustiala, K., & Victor, D. G. (2004). The regime complex for plant genetic resources. *International Organization*, *58*(2), 277–309.
91. Robiglio, T., Neri, M., Coppes, D., Agostinelli, C., Battiston, F., Lucas, M., & Petri, G. (2025). Synergistic signatures of group mechanisms in Higher-Order systems. *Physical Review Letters*, *134*(13). https://doi.org/10.1103/physrevlett.134.137401

92. Rotmans, J., & Loorbach, D. (2009). Complexity and transition management. *Journal of Industrial Ecology*, *13*(2), 184–196. https://doi.org/10.1111/j.1530-9290.2009.00116.x
93. Sawyer, R. K. (2005). *Social emergence: Societies as complex systems*. Cambridge University Press.
94. Schmidt, J. J., & Matthews, N. (2018). From state to system: Financialization and the water-energy-food-climate nexus. *Geoforum*, *91*, 151–159. https://doi.org/10.1016/j.geoforum.2018.03.001
95. Snellen, W. B., & Schrevel, A. (2004). *IWRM: For sustainable use of water – 50 years of international experience with the concept of integrated water resources management*(Alterra Report 1143). Alterra.
96. Stoeva, P. (2010). *New norms and knowledge in world politics: Protecting people, intellectual property and the environment*. Routledge.
97. Teisman, G., van Buuren, A., & Gerrits, L. (Eds.). (2009). *Managing complex governance systems: Dynamics, self-organization and coevolution in public investments*. Routledge.
98. UN ECOSOC. (1997). *Coordination of the policies and activities of the specialized agencies and other bodies of the United Nations system: Freshwater, including clean and safe water supply and sanitation (E/1997/100)*. United Nations Economic and Social Council.
99. United Nations. (1979). The role of the United Nations in water resources development. *Geojournal*, *3*(5), 471–479. https://doi.org/10.1007/BF00455986
100. United Nations. (1990). *Achievements of the International Drinking Water Supply and Sanitation Decade, 1981–1990: Report of the Secretary-General*. United Nations.
101. United Nations (1992). *Agenda 21: United Nations Conference on Environment and Development*. United Nations. https://www.un-documents.net/agenda21.htm
102. Vadrot, A. B. M. (2017). Knowledge, international relations and the structure–agency debate: Towards the concept of epistemic selectivities. *Innovation: The European Journal of Social Science Research*, *30*(1), 61–72.
103. Van Assche, K., Beunen, R., Verweij, S., Evans, J., & Gruezmacher, M. (2022a). No time for nonsense! The organization of learning and its limits in evolving governance. *Administration & Society*, *54*(7), 1211–1225. https://doi.org/10.1177/00953997221093695
104. Van Assche, K., Beunen, R., Verweij, S., Evans, J., & Gruezmacher, M. (2022b). Policy learning and adaptation in governance: A co-evolutionary perspective. *Administration & Society*, *54*(7), 1226–1254. https://doi.org/10.1177/00953997211059165
105. van Buuren, A. (2013). Knowledge for water governance: Trends, limits, and challenges. *International Journal of Water Governance*, *1*(1), 157–175. https://doi.org/10.7564/12-IJWG6
106. van Mierlo, B., & Beers, P. J. (2020). Understanding and governing learning in sustainability transitions: A review. *Environmental Innovation and Societal Transitions*, *34*, 255–269. https://doi.org/10.1016/j.eist.2018.08.002
107. Voß, J. P., & Kemp, R. (2006). Sustainability and reflexive governance: Introduction. In J. P. Voß, D. Bauknecht, & R. Kemp (Eds.), *Reflexive governance for sustainable development* (pp. 3–28). Edward Elgar.

108. Wagner, M. (2016). *Social emergence in international relations: Institutional dynamics in East Asia*. Palgrave Macmillan.
109. Woodhouse, P., & Muller, M. (2017). Water governance—An historical perspective on current debates. *World Development*, *92*, 225–241. https://doi.org/10.1016/j.worlddev.2016.11.014
110. World Bank, United Nations Development Programme, & Food and Agriculture Organization. (1995). *Water sector policy review and strategy formulation: A general framework*. FAO.
111. World Bank. (1993a). *Water resources management: A World Bank policy paper*. World Bank.
112. World Bank. (1993b). *New World Bank water policy stresses comprehensive approach [Press release]*. World Bank.
113. World Bank. (2004). *Water resources sector strategy: Strategic directions for World Bank engagement*. World Bank.
114. Yu, B. (2019). Cognitive evolution and the transformation of global climate governance. *World Economics and Politics*, (12), 101–133. (in Chinese).
115. Zürn, M. (2017). From constitutional rule to loosely coupled spheres of liquid authority: a reflexive approach. *International Theory*, *9*(2), 261–285. https://doi.org/10.1017/s1752971916000270
116. Zürn, M. (2018). The rise of the global governance system: A historical-institutionalist account. In M. Zürn (Ed.), *A theory of global governance: Authority, legitimacy, and contestation*. Oxford University Press. https://doi.org/10.1093/oso/9780198819974.003.0006