

## What makes a “regime complex” complex? It depends

Author: James Hollway

Graduate Institute of International and Development Studies, Geneva, Switzerland

Email: [james.hollway@graduateinstitute.ch](mailto:james.hollway@graduateinstitute.ch)

What makes the collections of international institutions or regimes governing various domains—called in the literature regime, institutional, or governance complexes—“complex”? This article examines several conditions for complexity discussed in that literature and finds them necessary but not sufficient. It argues that the sufficient condition is *dependence* and outlines a framework of increasing levels of synchronic (social/spatial) and diachronic (temporal) dependence. Putting dependence at the centre of discussions on regime complexes has four advantages: (1) it is analytically more precise a condition than proliferation or linkage; (2) it orients us toward questions of degree, ‘how complex’, instead of the binary ‘whether complex’; (3) it informs a range of research design and theoretical choices, especially highlighting extra-dyadic dependencies and an underdeveloped temporal dimension; and (4) it arguably reconciles competing uses of the term “complex” in the literature without conflating it with complexity, structure, or topology.

**Keywords:** regime complex; institutional proliferation; institutional interlinkages; network dependence; temporal dependence

### What is complex about a complex?

The collections of international institutions or regimes governing various domains are often called “complex”. Indeed, Alter and Raustiala (2018) maintain that “the signature feature of twenty-first century international cooperation is arguably not the regime but the regime complex”. While some prefer “institutional complexes” (Aggarwal, 1998; Oberthür and Stokke, 2012; Zelli and Asselt, 2013) or “governance complexes” (Underdal, 2010; Biermann et al., 2010; Hollway and Koskinen, 2016) to “regime complexes” (Raustiala and Victor, 2004; Keohane and Victor, 2011), all this work faces a similar question:<sup>1</sup> *what’s complex about a complex?*

For readers of this journal, the term “complex” may evoke special theoretical ideas such as complex adaptive systems (CAS; Morçöl, Teisman, and Gerrits, 2014; Teisman and Gerrits, 2014). But scholars of international cooperation seem more comfortable invoking these concepts with respect to the system to be governed (i.e. governance of complexity) than empirically applying them to the systems of governance themselves (i.e. complexity of governance) (Orsini et al., 2019; Biermann et al., 2020). Instead, it is more common to see the term “complex” used metaphorically to indicate a set of interacting institutions that represents a particular analytic challenge and thus demands different questions or different approaches. Herbert Simon (1962, p. 467) once said: “Metaphor and analogy can be helpful, or they can be misleading”. This paper therefore seeks to examine more closely how this term is used in the literature to identify what makes a regime complex ‘complex’.<sup>2</sup> In this paper, I argue that what makes complexes “complex” and such profound analytic challenges is not institutional multiplicity, diversity, overlap, or even interaction, as often argued or implied in the literature—these are necessary but not sufficient—but *dependence*.

Putting dependence at the centre of discussion on regime complexes is useful for four reasons. First, it helps refine analytic tools to concentrate on those features that matter most for “complexifying” domains. For example, it cautions against equating institutional proliferation with complexity; many

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<sup>1</sup> I thus use them interchangeably here.

<sup>2</sup> Note that here I am exploring the definitional features common to all complexes, i.e. proliferation, linkages, dependence,



units may make a domain complicated, but not *necessarily* complex. Second, relating complexity to dependence helps us to think of complexity not in binary terms—is it complex or not?—but rather in terms of degree. Some “complexes” (noun) will be more complex (adjective) than others, involving broader or deeper *degrees* of dependence. For example, are two, three, or more international institutions entangled or interdependent in their behaviour? Thinking of complexity in terms of degree demands that we think of theories and methodological approaches that are commensurate to the level of complexity in the system rather than just its presence. Third, dependence provokes us to consider complexity dimensionally, opening up different *kinds* of complexity. Dependence can exist not only among units synchronically, but also diachronically through time. Relating complexity to dependence rather than the existence of many (different) units emphasises temporal dependencies in a productive way. Lastly, dependence can reconcile work that conceives of complexes as a noun, akin to apartment or military complexes, with those that interpret complexes with more CAS-lenses. For example, it is where there is broad dependence among apartment units that we might say that there is a “complex” and where the operation of such dependencies can introduce emergence and nonlinearity.

The next section outlines my argument for why other features of complexes are only necessary whereas dependence is sufficient. I then follow with a first attempt to outline some orders, levels, or degrees of spatial and temporal dependence, illustrating their relevance to research design on regime complexes with a discussion on how case selection is impacted by each level of dependence. I then elaborate some additional methodological and theoretical implications, and conclude with an outlook on the use of the term complex in the literature.

## From Proliferation to Dependence

### *Proliferation: Multiplicity and Diversity*

A common answer to what makes regime complexes “complex” stems from this literature’s original observation of increasing institutional density. For example, Raustiala and Victor (2004), in their seminal piece, begin from the observation that international institutions have proliferated in the postwar period and argue that this makes it difficult to “decompose” the complex and study individual institutions.<sup>3</sup> Concentration on this original observation has produced two related variables being used to operationalize complexity: unit multiplicity and diversity (Biermann et al., 2020).

Multiplicity is implicit in many accounts. For example, Orsini, Morin and Young (2013, p. 27) highlight the complexity borne of institutional densification “as the number of new treaties has grown at an exponential rate and existing intergovernmental organizations have crept into neighboring issue areas”. They argue that a regime complex must consist of at least three elementary institutions. Asselt and Zelli (2014) also explicitly consider the number of institutions a useful measure of institutional complexity.

A similar argument is that it is not the number but the diversity of institutions that makes a system complex. Those who focus on the appearance of private and hybrid authority often advocate such a position (e.g. Gulbrandsen, 2010; Kalfagianni and Pattberg, 2013; Widerberg, 2016), though this is also broadly consistent with applications of organizational ecology (Abbott, Green, and Keohane, 2016; Morin, 2018).

However, while proliferation may be a necessary condition for complexity, it is not sufficient. A larger system may make complexity possible but not inevitable. Multiple and maybe even diverse units is an important condition but, if these units can be considered to operate independently of one another, the collection of units pose no special analytic challenge. A system with many independent units may still be entirely decomposable. For example, single-celled organisms might proliferate but

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<sup>3</sup> “Decomposability” here references Herbert Simon’s (1962) classic paper “The Architecture of Complexity”, in which he argued that, in contrast to the “decomposability” of many physical systems, many social systems are “nearly decomposable” in that there are weak but not negligible interactions among their subsystems.



even their aggregation alone may not be conceived of as particularly complex. Indeed, proliferation may represent more of a methodological opportunity than a challenge. After all, more institutions, say, could simply mean more cases with which to learn more about the institutional strategies that are most effective for different purposes and under different conditions. That is, institutional proliferation is a necessary but itself insufficient condition for institutional complexity.

#### *Linkages: Overlap and Interaction*

Another answer stems from early definitions of regime complexes that emphasise institutional linkages (e.g. Young, 1996; Keohane and Victor, 2011) or overlaps (e.g. Raustiala and Victor, 2004, p. 279). Concepts of overlap and interaction both build upon proliferation but go one step further.

The literature on overlap highlights how institutional complexity derives from the competing or synergistic effects of institutions that overlap in membership or mandate. Alter and Meunier (2009) argue that the “increasing density of international regimes has contributed to the proliferation of overlap across agreements, conflicts among international obligations, and confusion regarding what international and bilateral obligations cover an issue”. Zelli, Möller, and Asselt (2017, p. 670) understand institutional complexity as “a diversity of international institutions that legally or functionally overlap in addressing a given issue area of global governance”. A recognition that overlap is a necessary condition for complexity has resulted in a burgeoning literature examining how different types of overlap result in different kinds of outcomes or demand different strategies (Hofmann, 2011). But while overlap is a necessary condition for complexity, it is also not sufficient: overlapping institutions could simply have linear, additive effects on their mandates or members, and not interact either statistically or in terms more common to this literature.

The literature on interactions goes one step further, arguing that there is not just a common referent, but that it is the institutions themselves interacting to manage overlapping mandates that makes complexes “complex”. Raustiala and Victor (2004, p. 278) maintain that “the rising density of the international system makes it likely that interactions among regimes will be increasingly common”. Axelrod (2014, p. 987) asserts that more institutions increase the probability of “inconsistent legal commitments” that requires more interaction. As with the literature on overlap, a literature on institutional interactions (e.g. Oberthür and Stokke, 2011) has emerged to identify and explain different types of linkages, such as ideational, strategic, and normative. As such, this perhaps comes closest to identifying what makes a complex “complex”. However, as Kim (2019) highlighted, this literature has overwhelmingly sought to disaggregate and decompose larger systems into dyads of institutions so that the linkages could be treated as analytically similar (Stokke, 2012; Oberthür and Stokke, 2011). Just as complexes are thought to be more than the sum of their units, they also ought to be considered more than the sum of their dyads, given that they are typically larger than two institutions (Orsini, Morin, and Young, 2013).

To be clear: proliferation, diversity, overlap, and interaction are all necessary conditions for a set of regimes or institutions to be complex. Proliferation and diversity reference the necessary units for complexity. Overlap and interaction reference the necessary linkages among those units for complexity. However, they are also insufficient and more distal criteria of complexity. These linkages still offer only *opportunities* for inter-institutional influence and do not characterise or describe it. It is not just that there are multiple institutions somehow connected or linked; such a link needs to induce *dependence*.

#### *Dependence: Spatial and Temporal*

Consider Simon’s (1962) classic watchmaker parable. Two watchmakers are tasked with each constructing a watch of 1000 elementary units in the face of disturbance. However, while one adds each unit in turn and has to contend with everything falling apart upon disturbance, the other



constructs successive sets of stable subassemblies that mean their work, upon disturbance, is only destroyed to the last stable subassembly. Simon argues that it is the hierarchical layering of only near decomposability in the latter that represents complexity.

Simon's parable highlights why the number of units or relations between them are insufficient to characterise complexity. A watch of 1000 elementary units is not necessarily more complex than one of 500, nor is one of 1000 connections necessarily more complex than one of 500 connections. What makes a system more complex is that the units interact *such that they depend on one another*. Changing something in one part affects other parts. For example, reversing a component cog in a watch may make it not work, or work backwards, which may then affect yet further elements. Applied to institutional complexity, we might observe how an institution's membership, policies, or effectiveness might depend on the membership, policies, or effectiveness of other related institutions. Or a relationship between two institutions might depend on the presence or absence of relationships between each institution and other (third) institutions or actors.

So what is the distinction between linkages and dependence? Consider a wristwatch and its band.<sup>4</sup> While the two components are linked, there is not really any dependence here. The watch would continue to tell time without the band. In other words, formal linkages can incur no real dependencies. Institutionally, an example might be two institutions that observe each other's meetings for historical reasons without any kind of coordination or adjustment. Now consider the watch and a magnet. Here there is no formal linkage, but the magnet's presence can cause the hairspring component to seize, either shortening the active length of the spring and speeding up time or arresting the watch altogether. In other words, dependencies can appear even without observable linkages. Institutionally, an example might be institutions that operate in "conscious parallelism" (Abbott 2012, p. 583), adjusting mutually despite the absence of any formal linkage.

Dependence is similar to the concepts of cognitive interaction (Gehring and Oberthür 2009) or functional interdependence (Young 2002, p. 23) raised in the literature. But dependence offers a broader conceptual base in two important regards: it can be extra-dyadic and temporal. While most notions of interaction and linkage have focused tightly on institutional dyads, dependence can encompass broader setups in both degree and kind. First, dependence can expand beyond the dyad. This is important because, if such broader degrees of dependence are present, then decomposing a complex into supposedly constituent dyads can be misleading. Institutional dependencies are thus what makes governance so complex, because the presence of dependencies mean we can never do just one thing.

Second, dependence can be temporal too. So far, cross-sectional spatio-structural dependencies are the most obvious and studied to date in the literature on regime complexes. While temporal dependence has long been a focus in (historical) institutional theory (Pierson, 2000) and policy change, this work has had greater focus on how institutional arrangements persist than how novelty arises (see Hollway, Morin and Pauwelyn, 2020), and has not been well integrated into the study of institutional or regime complexes so far (excepting e.g. Andersen, 2002; Colgan, Keohane and Van de Graaf, 2011; Morin, Hollway and Pauwelyn, 2017). But as Morin and Gomez-Mera argue in Orsini et al. (2019, p. 20), the temporal dimension cannot be ignored. Dependence is a concept as sensitive to time as (social) space. Action reconfigures existing relationships, but the residue of those relationships often remain, making more things depend on one another than before (Hollway, 2020). In the following section, I outline a categorisation of sociospatial dependence that incorporates unit and linkage-based dependence, but also extends it to broader dependencies, as well as outlining corollaries for temporal dependence.

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<sup>4</sup> I thank an anonymous reviewer for this example.



## Orders of Dependence

Simon (1962, p. 481) said: “How complex or simple a structure is depends critically upon the way in which we describe it. Most of the complex structures found in the world are enormously redundant, and we can use this redundancy to simplify their description. But to use it, to achieve the simplification, we must find the right representation.” Various disciplines including computer science have considered ways to characterise complexity, such as by length or class. I propose to borrow from statistics—especially statistical network, time series, and sequence analysis—a formalisation of the notion of dependence to construct a scale of complexity. Though there could be various types, forms, and pathways of dependence, I follow Simon’s advice here to reduce down and simplify to two kinds or dimensions of dependence: synchronic or spatial dependence and diachronic or temporal dependence. Both are outlined here as forms of autocorrelation, in which observations may depend on other observations of the same variable, but this can quite simply be extended to other variables without loss of generality.

Table 1 below outlines a first attempt at classifying orders or degrees of synchronic and diachronic (in)dependence. For the synchronic or spatial configurations, the orders of dependence are highlighted on a hypothetical network of adjacency between five nodes  $\{i, j, k, l, m\}$ . One might imagine these as institutions identified in a given field or with some potential salience to one another. For the diachronic or temporal configurations, the orders of dependence are illustrated with a network of relationships between time points  $\{t, t-1, t-2, t-3\}$ . For synchronic dependence, we are interested in how a relationship between nodes  $i$  and  $j$  might depend on the six other ties in this hypothetical network. For diachronic dependence, we are interested in how time point  $t$  might depend on earlier time points, which is why the ties can only go back in time. In each figure, dependencies are shown as solid lines, whereas inactive or irrelevant relationships for that order of dependence are still shown, though as dashed lines only.

Each row represents an increasing order of dependence, from a null of complete independence for institutional observations across space or through time, to higher order configurations of dependence across space or time. So for example, Bernoulli independence means a relationship between institution  $i$  and institution  $j$  is independent of all other institutional linkages, including others between  $i$  and  $j$ , whereas circuit dependence suggests that that relationship depends on all other local institutional linkages. And whereas temporal noise suggests that the behaviour or effects of an institution(al complex) at time  $t$  is independent of any part of its history, juncture dependence suggests that all time points after  $t - 3$  depend on some institutional behaviour at that point. Note that synchronic dependence nests lower orders, whereas diachronic dependence involves different types.

Below I discuss synchronic or spatial dependence first and then temporal, but there is nothing to suggest one is more elementary than the other. Together they represent a useful way to think about how complex many social systems are, irrespective of their size, and offer a starting point for measuring relative complexity, a prerequisite for empirical investigations into whether and how this matters. I have included the formal representation of these dependencies in the table for completeness, but have kept the discussion in the text conceptual. I illustrate the consequentiality of successive orders of dependence, of both types, with reference to decisions of case selection where appropriate. In the following section, I outline some further methodological and theoretical implications.



Order	Synchronic/Spatial	Diachronic/Temporal
0	<p><i>Bernoulli</i></p> <p><math>X_{ij} \perp\!\!\!\perp X_{hk} \forall i, j, h, k \in \mathcal{N}</math></p>	<p><i>Noise</i></p> <p><math>X_t \perp\!\!\!\perp X_s \forall s &lt; t</math></p>
1	<p><i>Dyad</i></p> <p><math>X_{ij} \not\perp\!\!\!\perp X_{hk} \forall \{ij\} = \{hk\}</math></p>	<p><i>Trend</i></p> <p><math>X_t \not\perp\!\!\!\perp X_{t-1}</math></p>
2	<p><i>Markov</i></p> <p><math>X_{ij} \not\perp\!\!\!\perp X_{hk}</math> if <math>\{i, j\} \cap \{h, k\} \neq \emptyset</math></p>	<p><i>Season</i></p> <p><math>X_t \not\perp\!\!\!\perp X_{t-s}</math> where <math>s \in \mathbb{R}</math></p>
3	<p><i>Circuit</i></p> <p><math>X_{ij} \not\perp\!\!\!\perp X_{hk}</math> if <math>X_{ih} = X_{jk} = 1</math> or <math>X_{ik} = X_{jh} = 1</math></p>	<p><i>Juncture</i></p> <p><math>X_t \not\perp\!\!\!\perp X_s \forall t &gt; s</math></p>

Table 1: Synchronic and Diachronic Dependence

### *Social, spatial, or synchronic dependence*

Synchronic dependence references observational dependencies that are conditioned on some proximity or distance, whether in physical space (Neumayer & Plümper, 2010) or social space (Hollway et al., 2017; Knoke et al., 2021). Physical or geographical space is the more commonly understood, with distance measured in meters or miles. Social space is constructed by the links between social actors (or institutions), with distance measured in terms of degree (as in six degrees of separation) or path length between nodes. Both allow some kind of spatial mapping on the basis of these distances though, with the implication that neighborhoods of adjacent nodes can be identified in that space. In this subsection, I treat spatial and social structural dependencies together, as their cross-sectional quality and emphasis on neighborhoods make them analytically similar for our purposes. Moreover, spatial dependencies are often treated as networks to allow more flexible specification of what neighborhood or adjacency means (Juhl, 2019).

Statistical network models have been acknowledged as an improvement over traditional statistical models where researchers recognise the need to take into account or investigate dependencies between observations (e.g. Robins, Lewis, & Wang, 2012). The most elaborate hierarchy of structural dependence is defined in statistical network modeling for exponential random graph models (ERGMs) (Lusher, Koskinen, & Robins, 2013; Amati, Lomi, & Mira, 2018). ERGMs express the probability of observing a given network system as a function of subgraphs into which this network can be decomposed. An example of such a configuration is transitivity, known colloquially as “friends of my friends are likely also my friends”. Researchers might include such a configuration to improve their inference on some potentially correlated mechanism, such as homophily, or where they theorise that the opportunity structure afforded by shared contacts is consequential for ties between two individuals. Such subgraphs express local dependencies in the relationships or interactions between units (Pattison & Snijders, 2013). For our purposes, what is important is that specifications requiring more complex configurations to obtain a well-fitting model indicate broader dependencies. Four orders of structural dependence are defined and employed, from structural independence to circuit dependence.

First, ties that appear statistically independent of one another is typical of a *Bernoulli* or Erdos-Renyi model, which operates as our order zero of dependence complexity. For example, a claim that a system composed of one institution on local mining conditions or a single river basin might rightly be challenged as no complex system at all. This is, in a sense, our null model, and so we would expect to rarely observe their proposition. If an institutional complex were truly Bernoulli, then we could decompose “system” into its institutional components and analyse them separately without concern that we would be missing important dependencies.

Second, ties may depend (only) on other ties between that same *dyad*. The dyads themselves are independent, but all other interactions between that dyad must be considered and so the system is only decomposable to the dyad level. This includes reciprocating ties. If an institutional complex were “dyad independent”, this could facilitate the kind of examination Oberthür and Stokke (2011) outline in their work on institutional interaction. Dyadic studies have the chief advantage that they can allow for more elaborate consideration of all the different types of interlinkages that are possibly present but are inappropriate if higher levels of dependence are implicated. Examples include the interaction between the International Labour Organisation and the World Trade Organization (Gehring and Oberthür, 2009).

Third, ties may depend on immediately adjacent ties in a form of *Markovian* dependency. This generally means third units are involved. For example, the interaction between two institutions may depend on how they either or both interact with third institutions. If an institutional complex is “Markov dependent”, institutions should be examined as at least triads, though following this logic may quickly extend to larger groupings. That is, configurations of multiple interactions become a single dependence structure. A contemporary application of this might be the study of the Biodiversity



Beyond Areas of National Jurisdiction negotiations (De Santo et al. 2019; Vadrot 2020). These scholars have been studying the dependencies induced by the introduction of additional institutional concerns to the negotiations: the CBD, CITES, UNCLOS, FAO, a number of different Regional Fisheries Management Organizations, etc. The existing interactions between any two of these institutions will be affected by the introduction of a BBNJ institution, highlighting these dependencies.

Lastly, ties may be partially conditional on ties that are not immediately adjacent but appear in a *circuit* (Snijders et al., 2006). This represents the most complex substructures currently modelled in statistical networks, and yet is quite common in social networks. It reflects how ties between two units may depend on ties between two other units if those pairs of units are somehow connected. For example, the United Kingdom acts in the United Nations Security Council influenced by the relationship of the United States to the North Atlantic Treaty Organization, since the US is also a member of the UNSC and the UK is also a member of NATO. Such dependence is likely to be even more prevalent in the study of multilevel governance (e.g. Betsill and Bulkeley 2006) or when conceiving of collective action problems as not only horizontal and functional but also vertical (e.g. Feiock 2013; Knoke et al., 2021). This level of dependence may not result in much broader complexes than if only Markov dependence is considered, but its existence does introduce further analytic challenges within the complex.

#### *Temporal or diachronic dependence*

Diachronic dependence references observational dependencies that are conditioned on time. A hierarchy of temporal dependence is less well developed in the statistical literature, partly because temporal dependence has been treated through several different methods, including time series analysis (Hamilton, 1994), event history analysis (Allison, 1984), and sequence analysis (A. Abbott, 1995). Here I propose a hierarchy of temporal dependence concerned with how past information impacts expectations for the present that roughly relates to the orders of spatial complexity outlined in the previous subsection.

First, a lack of temporal dependence can be characterised as a random walk or white *noise* in a time series. No information about the present state or an institution or a complex can be gleaned from its past states. In an autocorrelation function, this would show as the absence of any significant correlation with past values at any step removed from the current observation. If past states of an institutional complex hold no information for its present state, then a wholly cross-sectional approach is perfectly appropriate. However, this is likely to be extraordinarily rare—it would suggest that there is absolutely no memory to institutionalised cooperation—which highlights why it is important to push the study of institutional complexity in more historical and dynamic directions.

Second, observations may depend on the previous observation(s). A *trend* takes as information the current trajectory, identified in the high autocorrelation with observations lagged by 1 and less autocorrelation with observations at increasing lags. This can also be characterised as a form of Markovian dependence, as information relevant to the present is held no more than one step away. Depending on how successive lags are correlated, this could also be represented as autoregressive, moving average, or exponentially smoothed. Institutional complexes subject to a trend may at least partly represent the continuation of processes already underway, and so even if researchers settle upon a cross-sectional approach, they need to be conscious of which aspects are part of this trend. Periodisation is difficult without at least an informative historical account preceding the cross-sectional analysis (Isaac and Griffin, 1989). Better is a temporal analysis that identifies the slope and length of the current trend, and whether it is linear or nonlinear. A common example of this approach is to study difference or change, say in institutional effectiveness (Mitchell, 2002): is chemical pollution trending down or up under a regime's influence?

Third, observations may depend on previous observations that are not immediately prior but defined at some regular or *seasonal* interval. Seasonal cycles are common in economic systems but



appear in political systems too as regular periods of policymaking, chairmanship alternations or rotations, or oscillations in public attention (Goetz and Meyer-Sahling, 2009). Somewhat more complex cycles can appear too. For example, electoral cycles may be somewhat irregular or lie out of step with one another, introducing some advantages to the continuity of an institutional complex in terms of the actors they represent as well as challenges. Identifying such complexity can pose an empirical challenge however, for it will require a certain maturity for the system to be able to identify such seasonality. But where seasonality does exist, say for example with the chemical pollution example above, it will be important to adjust for it.

Fourth, observations may depend on a previous observation having happened at some point in the past, and all later events will depend somewhat on the realisation of this *junction*. Historical institutionalism demands this degree of temporal dependence, as significant events in the past can switch trajectories onto different paths that then get “locked in” through increasing returns to that switching event (Pierson 2000; see also Rixen and Viola 2014; Hanrieder 2015). This might be the introduction of a new institution to the complex, or a policy change within one of the institutions (that then percolate through the system according to Markovian or circuit dependencies outlined above). The introduction of BBNJ will irrevocably alter other interinstitutional relationships, for example. Repetition may also be part of this order of temporal dependence: it may matter if an institution has ever done something, or the sequence of events (Thornton and Ocasio 2008), not how long ago it was. For example, an institution that has been seen to be effective in a crisis may enjoy greater legitimacy, enabling strategies and policies that would have otherwise lain out of reach. Or an institution that is strongly associated with a particular blunder, for example the League of Nations, may never recover, no matter how much time elapses. If junctures are present, this can imply two things for research designs. If the goal is to identify the effectiveness of any policy associated with the juncture point, then the design will need to cover a period both prior and following the critical event to identify the effects that event had. But if the goal is simply to forecast, then only the complex’s history after the juncture point will be salient.

Of course, some degree of dependence will almost always be present in sociopolitical systems. Because of this, asking whether a system or setting is a “complex” or not is misleading. The more consequential and productive question is which kinds and degrees of dependence are present. We have seen in this section how the presence of particular orders of dependence have implications for case selection. In the following section, I outline some further methodological and theoretical implications.

## Methodological and Theoretical Implications

Taking a perspective on complexity that is conscious of the scope of (structural or temporal) dependency has important methodological and theoretical implications. *Complexity is consequential because dependence frustrates our ability to make inferences about institutional influences and impacts independently of actors and institutions related through space and time.* In introducing spatial and temporal orders of complexity, I have already outlined how case selection might be impacted by the maximum level of dependence present in a system. Indeed, characterising complexity as dependence highlights *why* the biggest challenge in studying regime complexes is where the appropriate analytic boundary lies (Orsini, Morin, and Young, 2013). But here I also outline some other aspects of research design affected by the order of complexity present in a set of institutions: sampling, prediction, replication, and theory-building.

First, a key part of traditional statistics and its assumption of independent observations is *sampling*. Simple random sampling is the gold standard because it provides an unbiased way of surveying a population. This is why Koremenos (2013) employs it to support generalisable statements about a population of international institutions. However, dependence impacts the logic of such a strategy. Random sampling excises observations from their context in the population. If institutions are, say, Markov dependent, then observing an institution at random from that population will mean



missing other (actors and) institutions on which it is dependent, introducing bias another way. Each missing observation thus represents  $n-1$  missing dyadic observations. This drives us towards the collection and development of more purposive and comprehensive populations of international institutions in different domains. Fortunately, institutional complexes are comparatively small systems and information about constitutive relations if not interactions are often of public record, encouraging at least the ambition for comprehensive datasets on international institutions.

Another aspect of traditional statistics impacted by dependence and complexity is *generalisability*. A recognition that higher orders of complexity exist raises the questions: to what we are generalising? What is the population? While explicit transposition of insights from institutional complex to institutional complex is rare in contemporary scholarship, scholars often implicitly suggest that their findings in one domain are transportable to others. Higher orders of spatial dependency highlight how it is not simply the parts that must be commensurate for translation, but that there may be different types of Markovian or circuit dependencies in play without correspondence in other settings. Moreover, higher orders of temporal dependency highlight how baseline trends may be stronger in one regime than another, or that particular junctures in one regime may be absent or framed in a different way in another. One option forward is to avoid generalising variables and instead seek lessons on the level of mechanisms (Tilly, 2001; Hedström & Ylikoski, 2010). These mechanisms can concatenate in complex ways to generate quite different, even idiosyncratic systems in time, but also provide portable insights into complex phenomena (Epstein, 1999). I would argue that particularly fruitful “mechanisms” for the sociopolitical world where we are ever concerned with agency in the face of complexity are those that might explain actors’ choices (Hollway, 2020; see also Block et al., 2018), for they offer us a way of understanding and acting in a social world.

*Prediction*, often touted as the gold standard of statistical models, is another aspect dependence touches upon. Epstein (2008) enumerates sixteen reasons other than prediction to build models. These include explanation and theory-testing (quite distinct from prediction), but also the illumination of micro-macro linkages, the suggestion of dynamical analogies, prompting new questions and guiding data collection or case selection, for pedagogical and public education purposes, and to discipline the policy dialogue by identifying risks, efficiencies, and trade-offs. We can and should build statistical models of institutional complexes for all these purposes, to build scenarios and inform policy decisions, to understand the past and our future options. But prediction is not just only one among many purposes of statistical models, it can sometimes be an unhelpful metric in the context of complexity (Orsini et al., 2019). After all, spatial and temporal dependencies may be such that prediction is either trivial or impossible. For example, we might predict an institutions policy from what it had implemented yesterday (trend dependence), but this does not help us understand or act in the world. But predicting an institution’s membership or policy in just ten years nonetheless demands courageous assumptions about (a lack of) spatial and temporal dependence (Cederman and Weidmann 2017). Instead, we might think about fit in terms of whether simulations from our models replicate core dependencies (Block et al., 2018).

Lastly, a concentration on dependence also has theoretical implications. It highlights the importance of studying the conditions under which proliferation leads to linkage (e.g. Hofmann, 2019), and linkage leads to different degrees of dependence (e.g. Oberthür & Gehring, 2006). But it also highlights how we also need to further theorise how institutions and regimes depend on one another through time. The literature to date has been overwhelmingly cross-sectional, and yet temporal dependencies of the sort outlined here are surely as prevalent. This means bringing the sort of work prevalent in regime complexity and historical institutionalism closer together. Thinking through how spatially and temporally dependent a particular governance domain is points us not only to methodological adaptations that must be made, but also (as it always has for the regime complexity literature) where the interesting questions are.

Introducing more temporal and spatial dimensions is both data intense and analytically intensive. On the data side, accepting the presence of (higher levels of) dependence means thinking



carefully about the boundaries of regime complexes, what data is available, and what further data would need to be collected so as not to miss important dependencies thought to be present. On the analysis side, dependencies demand the use of methods, for example network and sequence analysis, that can not only account for dependencies in their evaluation of uncertainty surrounding estimates, but present such dependencies in the estimates themselves as representative of mechanisms of theoretical interest. The implications of recognising dependence in regime complexes is thus demanding. The alternative would be to act as if such dependencies were not present or were irrelevant. But their presence and relevance, I have argued, is the premise of regime complexity.

## Outlook

I have argued here that the feature of institutional complexes that makes them complex in the sense of analytically challenging is not the number or diversity of institutions or linkages between them, though these are necessary conditions, but rather that these linkages induce dependencies that make it difficult to analytically decompose the institutional complex or act within it. I then elaborated this notion of dependence into classes or orders of spatial and temporal dependence and related these to particular demands in terms of the chief research design question of institutional complexes: boundary specification. I have concluded by discussing some further theoretical and methodological implications of a concentration on dependence, including brief considerations for what this means for sampling international cooperation, the possibilities of replication, generalization, and prediction, as well as how this pushes the literature to consider temporal dependencies in institutional complexes as much as spatial dependencies.

Characterising complexity as dependence is consistent with much of the current literature. For example, Orsini, Morin, and Young (2013, p. 27) contrast current trends with “earlier times” in which “most intergovernmental organizations (IGOs) and multilateral treaties were relatively independent from one another”. Moreover, identifying higher-order dependence as the sufficient condition for a complex is consistent both with those that use the term complex as noun (e.g. military industrial complex) and those who use it as adjective (e.g. complex systems). For example, Eisenhower’s 1951 speech highlighted how legislators, the military, and the defence industry were becoming increasingly dependent upon one another and can therefore represent some identifiable aggregate that would lead to bias if we were to analytically decompose. Moreover, features of complex adaptive systems such as feedbacks, nonlinearity, and learning all represent dependence. A concentration on which orders of dependence are prevalent could therefore offer a way to square the circle, as it were, between these literatures.

Is complexity and dependence the same thing then? I think it behooves us to keep these conceptually distinct. This means we can highlight their relationship and identify how institutional dependence is a sufficient condition for but also a response to complexity (see also Le Prestre, 2017). Only by incorporating temporal dependence more explicitly can we parse out when and how dependence affects complexity and vice versa (Pantzerhielm et al. 2020). The dependence hierarchy outlined here allows us to recognise that higher-order dependencies may be more prevalent in some domains than others, and reflect on the research design and theoretical implications thereof. Likewise, this discussion highlights how questions of complexity and structure or topology differ and should not be treated as interchangeable, at least if we aim for more precise terminology in this field.

Lastly, a conceptual toolkit such as that outlined here allows us to formalise the relationship between dependence and complexity, supporting more explicit research designs that correspond to the theoretical assumptions of the literature, and in turn promote the identification of further research frontiers and their properties. Most prominently, identifying dependence at the root of this literature highlights the relative paucity of work on temporal dependence and regime complex dynamics. The challenge will be to develop this theoretically: yes it depends, but on what?



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## References

- Abbott, Andrew (1995). “Sequence analysis: New methods for old ideas”. In: *Annual Review of Sociology* 21, pp. 93-113.
- Abbott, Kenneth W (2012). “The Transnational Regime Complex for Climate Change.” In: *Environment and Planning C* 30.4, pp. 571–90.
- Abbott, Kenneth W, Jessica F Green, and Robert O Keohane (2016). “Organizational Ecology and Institutional Change in Global Governance”. In: *International Organization* 70.2, pp. 247–277.
- Aggarwal, Vinod K, ed. (1998). *Institutional Designs for a Complex World: Bargaining, Linkages & Nesting*. Ithaca, NJ: Cornell University Press.
- Allison, Paul D (1984). *Event history analysis. Regression for longitudinal event data*. London: Sage.
- Alter, Karen J and Sophie Meunier (2009). “The Politics of International Regime Complexity”. In: *Perspectives on Politics* 7.1, pp. 13–24.
- Alter, Karen J and Kal Raustiala (2018). “The Rise of International Regime Complexity”. In: *Annual Review of Law and Social Science* 14.1, pp. 329–349.
- Amati, Viviana, Alessandro Lomi, and Antonietta Mira (2018). “Social Network Modeling”. In: *Annual Review of Statistics and Its Application* 5.1, pp. 343–369.
- Andersen, Regine (2002). “The Time Dimension in International Regime Interplay.” In: *Global Environmental Politics* 2.3, pp. 98–117.
- Asselt, Harro van and Fariborz Zelli (2014). “Connect the dots: managing the fragmentation of global climate governance”. In: *Environmental Economics and Policy Studies* 16.2, pp. 137– 155.
- Axelrod, Mark (2014). “Clash of the treaties: Responding to institutional interplay in European Community-Chile swordfish negotiations”. In: *European Journal of International Relations* 20.4, pp. 987–1013.
- Betsill, Michele M, and Harriet Bulkeley (2006). “Cities and the Multilevel Governance of Global Climate Change.” In: *Global Governance* 12, pp. 141–59.
- Biermann, Frank, Fariborz Zelli, Philipp H Pattberg, and Harro van Asselt (2010). “The architecture of global climate governance: setting the stage”. In: *Global Climate Governance Beyond 2012: Architecture, Agency and Adaptation*. Cambridge: Cambridge University Press, pp. 15–24.
- Bierman Frank, Rakhyun E Kim, Kenneth W Abbott, James Hollway, Ronald B Mitchell, and Michelle Scobie. (2020). “Taking Stock and Moving Forward.” Pp. 299–321 in *Architectures of Earth System Governance*, edited by F. Biermann and R. E. Kim. Cambridge: Cambridge University Press.
- Block, Per, Johan H. Koskinen, James Hollway, Christian E. G. Steglich, and Christoph Stadtfeld (2018). “Change We Can Believe in: Comparing Longitudinal Network Models on Consistency, Interpretability and Predictive Power.” *Social Networks* 52: 180–91.
- Cederman, Lars-Erik and Nils B. Weidmann (2017). “Predicting Armed Conflict: Time to Adjust Our Expectations?” *Science* 355: 474–76.
- Colgan, Jeff D, Robert Owen Keohane, and Thijs Van de Graaf (2011). “Punctuated equilibrium in the energy regime complex”. In: *The Review of International Organizations* 7.2, pp. 117– 143.
- De Santo, E, A Asgeirsdottir, A Barros-Plataiu, F Biermann, J Dryzek, LR Gonçalves, RE Kim, E Mendenhall, R Mitchell, E Nyman, M Scobie, K Sun, R Tiller, DG Webster, and O Young (2019). “Protecting Biodiversity in Areas Beyond National Jurisdiction: An Earth System Governance Perspective.” In: *Earth System Governance* 2:100029.
- Epstein, Joshua M (1999). “Agent-based computational models and generative social science”. In: *Complexity* 4.5, pp.41–60.
- (2008). “Why model?” In: *Journal of Artificial Societies and Social Simulation* 11.4, p. 12.
- Feiock, Richard C (2013). “The Institutional Collective Action Framework.” In: *Policy Studies Journal* 41.3, pp. 397–425.
- Gehring, Thomas and Sebastian Oberthür (2009). “The Causal Mechanisms of Interaction between International Institutions”. In: *European Journal of International Relations* 15.1, pp. 125–156.
- Goetz, Klaus H, and Jan-Hinrik Meyer-Sahling (2009). “Political time in the EU: Dimensions, perspectives, theories”. In: *Journal of European Public Policy* 16.2, pp. 180–201.
- Gulbrandsen, Lars H (2010). *Transnational Environmental Governance. The Emergence and Effects of the Certification of Forests and Fisheries*. Edward Elgar Publishing.
- Haftel, Yoram Z and Stephanie C Hofmann (2019). “Rivalry and Overlap: Why Regional Economic Organizations Encroach on Security Organizations”. In: *Journal of Conflict Resolution* 63.9, pp. 2180–2206.



- Hamilton, James D (1994). *Time Series Analysis*. Princeton: Princeton University Press.
- Hanrieder, Tine (2015). “The Path-Dependent Design of International Organizations: Federalism in the World Health Organization.” In: *European Journal of International Relations* 21.1, pp. 215–39.
- Hedström, Peter and Petri Ylikoski (2010). “Causal Mechanisms in the Social Sciences”. In: *Annual Review of Sociology* 36.1, pp. 49–67.
- Hofmann, Stephanie C (2011). “Why Institutional Overlap Matters: CSDP in the European Security Architecture”. In: *JCMS: Journal of Common Market Studies* 49.1, pp. 101–120.
- (2019). “The politics of overlapping organizations: hostage-taking, forum-shopping and brokering”. In: *Journal of European Public Policy* 26.6, pp. 883–905.
- Hollway, James (2020). “Network Embeddedness and the Rate of Water Cooperation and Conflict.” Pp. 87–113 in *Networks in Water Governance*, edited by Manuel Fischer and Karin Ingold. Cham: Palgrave.
- Hollway, James and Johan H Koskinen (2016). “Multilevel Embeddedness: the Case of the Global Fisheries Governance Complex.” *Social Networks* 44, pp. 281–94.
- Hollway, James, Alessandro Lomi, Francesca Pallotti, and Christoph Stadtfeld (2017). “Multilevel Social Spaces: the Network Dynamics of Organizational Fields.” *Network Science* 5.2, pp. 187–212.
- Hollway, James, Jean-Frédéric Morin, and Joost Pauwelyn (2020). “Structural Conditions for Novelty: The Introduction of New Environmental Clauses to the Trade Regime Complex.” *International Environmental Agreements: Politics, Law and Economics* 20.1, pp. 61–83.
- Isaac, Larry W. and Larry J. Griffin (1989). “Ahistoricism in Time-Series Analyses of Historical Process: Critique, Redirection, and Illustrations From U.S. Labor History.” *American Sociological Review* 54.6, pp. 873–90.
- Juhl, Sebastian (2019). “The Sensitivity of Spatial Regression Models to Network Misspecification”. *Political Analysis* 28(1): 1–19.
- Kalfagianni, Agni and Philipp H Pattberg (2013). “Fishing in muddy waters: Exploring the conditions for effective governance of fisheries and aquaculture”. In: *Marine Policy* 38, pp. 124– 132.
- Keohane, Robert Owen and David G Victor (2011). “The regime complex for climate change”. In: *Perspectives on Politics* 9.1, pp. 7–23.
- Kim, Rakhyun E (2019). “Is Global Governance Fragmented, Polycentric, or Complex? The State of the Art of the Network Approach”. In: *International Studies Review* 30.4, pp. 1–29.
- Knoke, David, Mario Diani, James Hollway, and Dimitris C Christopoulos (2021). *Multimodal Political Networks*. Cambridge: Cambridge University Press.
- Koremenos, Barbara (2013). “The Continent of International Law”. In: *Journal of Conflict Resolution* 57.4, pp. 653–681.
- Le Prestre, Philippe G (2017). *Global Ecopolitics Revisited: Towards a Complex Governance of Global Environmental Problems*. London: Routledge.
- Lusher, Dean, Johan H Koskinen, and Garry L Robins, eds. (2013). *Exponential Random Graph Models for Social Networks: Theory, Methods and Applications*. Cambridge, UK: Cambridge University Press.
- Mitchell, Ronald B (2002). “A quantitative approach to evaluating international environmental regimes”. In: *Global Environmental Politics* 2.4, pp. 58–83.
- Morçöl, Göktug, Geert Teisman, and Lasse Gerrits (2014). “Complexity, Governance, and Networks: Introduction to the Inaugural Issue”. In: *Complexity, Governance & Networks* 1.1, pp. 1–4.
- Morin, Jean-Frédéric, Joost Pauwelyn, and James Hollway (2017). “The Trade Regime as a Complex Adaptive System: Exploration and Exploitation of Environmental Norms in Trade Agreements.” *Journal of International Economic Law* 20.2, pp. 365–90.
- Morin, Jean-Frédéric (2018). “Concentration despite competition: The organizational ecology of technical assistance providers”. In: *The Review of International Organizations* 70.2, pp. 1– 33.
- Neumayer, Eric and Thomas Plümper (2010). “Spatial Effects in Dyadic Data”. In: *International Organization* 64.1, pp. 145–166.
- Oberthür, Sebastian and Thomas Gehring (2006). “Institutional Interaction in Global Environmental Governance: The Case of the Cartagena Protocol and the World Trade Organization”. In: *Global Environmental Politics* 6.2, pp. 1–32.
- Oberthür, Sebastian and Olav Schram Stokke, eds. (2011). *Managing Institutional Complexity: Regime Interplay and Global Environmental Change*. Cambridge, MA: The MIT Press.
- Orsini, Amandine, Philippe G Le Prestre, Peter M Haas, Malte Brosig, Philipp H Pattberg, Oscar Widerberg, Laura Gomez-Mera, Jean-Frédéric Morin, Neil E Harrison, Robert Geyer, David Chandler, and Chandl (2019). “Forum: Complex Systems and International Governance”. In: *International Studies Review*, pp. 1–31.
- Orsini, Amandine, Jean-Frédéric Morin, and Oran R Young (2013). “Regime Complexes: A Buzz, a Boom, or a Boost for Global Governance?” In: *Global Governance* 19, pp. 27–39.
- Laura, Pantzerhielm, Holzscheiter Anna, and Bahr Thurid (2020). “Governing Effectively in a Complex World? How Metagovernance Norms and Changing Repertoires of Knowledge Shape International Organization Discourses on Institutional Order in Global Health.” In: *Cambridge Review of International Affairs*.
- Pattison, Philippa E and Tom A B Snijders (2013). “Modeling Social Networks: Next Steps”. In: *Exponential Random Graph Models for Social Networks: Theory, Methods, and Applications*. Ed. by Dean Lusher, Johan H Koskinen, and Garry L Robins. Cambridge, UK: Cambridge University Press, pp. 287–301.



- Pierson, Paul (2000). "The limits of design: Explaining institutional origins and change". In: *Governance: An International Journal of Policy, Administration, and Institutions* 13.4, pp. 475–499.
- Raustiala, Kal and David G Victor (2004). "The regime complex for plant genetic resources". In: *International Organization* 58, pp. 277–309.
- Rixen, Thomas, and Lora Anne Viola (2014). "Putting Path Dependence in Its Place: Toward a Taxonomy of Institutional Change." In: *Journal of Theoretical Politics* 27.2, pp. 301–23.
- Robins, Garry L, Jenny M Lewis, and Peng Wang (2012). "Statistical Network Analysis for Analyzing Policy Networks". In: *Policy Studies Journal* 40.3, pp. 375–401.
- Simon, Herbert Alexander (1962). "The architecture of complexity". In: *Proceedings of the American Philosophical Society* 106.6, pp. 467–482.
- Snijders, Tom A B, Philippa E Pattison, Garry L Robins, and Mark S Handcock (2006). "New Specifications for Exponential Random Graph Models". In: *Sociological Methodology* 36.1, pp. 99–153.
- Stokke, Olav Schram (2012). *Disaggregating International Regimes: A New Approach to Evaluation and Comparison*. Cambridge, MA: MIT Press.
- Teisman, Geert and Lasse Gerrits (2014). "The Emergence of Complexity in the Art and Science of Governance". In: *Complexity, Governance & Networks*, pp. 17–28. 24
- Thornton, Patricia H, and William Ocasio (2008). "Institutional Logics." In: *The SAGE Handbook of Organizational Institutionalism*, edited by Royston Greenwood, Christine Oliver, Thomas B Lawrence, and Renate E Meyer, pp. 99–128. London: Sage.
- Tilly, Charles (2001). "Mechanisms in political processes". In: *Annual Review of Political Science* 4.1, pp. 21–41.
- Underdal, Arild (2010). "Complexity and challenges of long-term environmental governance". In: *Global Environmental Change* 20.3, pp. 386–393.
- Vadrot, Alice B. M. 2020. "Multilateralism as a 'Site' of Struggle Over Environmental Knowledge: the North-South Divide." *Critical Policy Studies* 14(2): 233–45.
- Widerberg, Oscar (2016). "Mapping institutions and actors in global climate governance: A network approach". In: *Environmental politics and governance in the Anthropocene*. Ed. by Philipp H Pattberg and Fariborz Zelli, pp. 95–116.
- Young, Oran R (1996). "Institutional Linkages in International Society: Polar Perspectives". In: *Global Governance* 2, pp. 1–24.
- Young, Oran R (2002). *The Institutional Dimensions of Environmental Change: Fit, Interplay, and Scale*. Cambridge, MA: MIT Press.
- Zelli, Fariborz and Harro van Asselt (2013). "Introduction: The Institutional Fragmentation of Global Environmental Governance: Causes, Consequences, and Responses". In: *Global Environmental Politics* 13.3, pp. 1–13.
- Zelli, Fariborz, Ina Möller, and Harro van Asselt (2017). "Institutional complexity and private authority in global climate governance: the cases of climate engineering, REDD+ and short-lived climate pollutants". In: *Environmental Politics* 26.4, pp. 669–693.