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Shared expectations and connected games in economic resource governance

Habilitation Thesis

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Abstract

This habilitation thesis contributes to the economics of common-pool resource extraction and the related provision of public goods in applied settings of natural resource and infrastructure governance. The focus is on the role of shared expectations and coordination as part of the logics and 'stakes' of interdependent decision-making, resulting from physical and institutional connectedness of economic games. This concerns isolated situations such as common-pool resource extraction, as well as connected situations and underlying games of public goods provision like interdependent collective decisions on infrastructure investment and use, which together form an 'ecology of games'.

The first four articles focus on the role of individual and shared expectations in empirical settings of interdependent decision-making, revealing their behavioral relevance in the context of industrial organization, coordination in infrastructure, natural resource, and energy governance. The fifth article builds on article two and extends the connected games of common-pool resource extraction and public goods provision to the broader 'ecology of games' in natural resource governance, demonstrating the importance of integrating connected games that are adjacent to the focal game that produces the operational outcome of interest. The article applies institutional economics theory and several basic game-theoretic models to the situational analysis via games. It contributes to understanding, structuring, and analyzing the logics of connected games– with a strong emphasis on empirical applications. The sixth article provides a theoretical contribution and synthesis to capture the diversity of games in empirical settings of connected games. The seventh article systematically reviews the empirical research literature that studies networks of action situations and the ecology of games in natural resource and infrastructure governance.

Declaration

This habilitation commentary has been proofread with the assistance of the tool Grammarly.

1 Introduction

Which role do expectations play in economic behavior? How do they influence industrial organization? How do they matter in collective action for public goods provision and common-pool resource governance? Which role do interdependencies between connected games play in this regard, and how do they shape natural resource and related infrastructure governance? These guiding research questions form the core of my habilitation thesis.

The thesis includes five empirical analyses, a theoretical synthesis contribution, and a review of empirical research on the economics of public goods and related common-pool resource extraction in applied settings of natural resource, infrastructure, and energy governance. The empirical research presented in this thesis builds on three major theoretical literatures, including expectations in decision-making, connected games, and polycentricity theory.

The first four articles focus on the role of individual and shared expectations in four empirical settings of interdependent decision making, revealing their behavioral relevance in the context of very different applications. The last three articles extend the analysis and theory to interdependencies between games. They include a theoretical synthesis contribution on archetypal games, a review of related empirical research, and an empirical analysis of connected games and the broader 'ecology of games' in natural resource governance, revealing the importance of considering and integrating connected games that are adjacent to the focal game, which produces the operational outcome of interest.

Table 1 lists all articles and the journals where they have been published. Specifically, the thesis includes four articles on the (1) role of individual expectations in supply chain governance, (2) the role of shared expectations in coordination problems, (3) the development of shared expectations via participatory modeling, and (4) the role of normative expectations and shared visions in energy modeling (see Table 1). Subsequently, and partially building on Article 2, the thesis includes three articles on the ecology of connected games in economic governance, including (5) empirical research on water and energy governance for irrigation, (6) a theoretical contribution to the tractability of games via archetypes, and (7) a review of the empirical literature on the ecology of games.

	Title	Journal
1	Behavioral determinants of supply chain integration and coexistence	Journal of Forest Economics
2	Empowering irrigation: A game-theoretic approach to electricity utilization in Indian agriculture	Utilities Policy
3	Participatory modelling updates expectations for individuals and groups, catalyzing behavior change and collective action in nexus governance	Earth´s Future
4	Visions before models: The ethos of energy modeling in an era of transition	Energy Research & Social Science
5	Assessing action situation networks: a configurational perspective on water and energy governance in irrigation systems	Water Economics and Policy
6	Archetypal games generate diverse models of power, conflict, and cooperation	Ecology & Society
7	Networks of action situations: a systematic review of empirical research	Sustainability Science

Table 1: Articles that form part of the habilitation thesis

The thesis commentary is organized as follows. Section 2 provides a brief introduction to the economic theory of expectations, coordination, connected games, and polycentricity, and includes a short literature review that highlights the research gap addressed by each article. In the main part of Section 3, the articles are briefly summarized, and conclusions are drawn for each contribution to their respective field of economic theory. Subsequently, a general discussion reflects the context of the three theoretical literatures. A short conclusion summarizes the thesis and provides an outlook for future research. The last section provides the author's contributions. All articles that form part of this habilitation thesis are accessible via doi links in the Appendix.

2 Literature review

How important are subjective expectations in shaping economic behavior? Although the relevance of expectations has been acknowledged in economic theory for at least three centuries and formalized as subjective expected utility seven decades ago (Moscati 2019), the relevance of heterogeneous subjective expectations had been largely ignored until recently (D'Acunto and Weber 2024). Subjective expectations only received increasing attention thanks to the advent of behavioral economics and the spread of experimental economic methods. Since then, an entire section in a handbook on experimental economics has been dedicated to uncertainty and information (Plott and Smith 2008), while a recently published handbook focuses exclusively on expectations (Bachmann et al. 2023).

Subjective expectations play a fundamental role in both individual decision-making and microeconomic behavior, as well as in macroeconomics (Bachmann et al. 2023). They also matter in the provision of public goods, common-pool resource governance, and related coordination problems (Runge 1981). Realizing the ubiquity of coordination problems in economic resource governance (Runge 1981; Isaac et al. 1989; Devetag and Ortmann 2007; Curry et al. 2019), the central role of expectations therein (Runge 1981; Medina Sierra 2007), and building on my earlier theoretical and empirical work originating from my dissertation research on coordination failures (Kimmich 2012, 2013a; Villamayor-Tomas et al. 2015; Kimmich 2016), I decided to more deeply investigate the role of expectations in the industrial organization of natural resource industries (Section 3.1) and in public goods provision and coordination (Section 3.2). Building on the idea of mental models and their relevance in expectations formation, I also decided to study the behavioral effects of participatory modeling on updating expectations, including shared expectations and their relevance for collective action, employing an intervention study in the empirical context of the water–energy–food nexus (Section 3.3). This acquired knowledge helped me to conceptualize the role of shared positive and normative expectations in energy model development and use in energy policy (Section 3.4).

The empirical research for the game-theoretic model in Section 2 also guided the path to the second major part of my habilitation thesis. In coordination games with multiple equilibria, expectation formation not only depends on the payoff structure of the focal

game but may also be influenced by strategies and outcomes of connected games that affect the payoff structure in the coordination game. More generally, the equilibrium outcomes of any focal game may depend on equilibrium outcomes in other, connected games, when payoffs are influenced by connected games (McGinnis 2011). Such networks or 'ecologies of games' play a crucial role in many infrastructure and resource governance domains. The related literature is reviewed in Section 2.2.

The study of 'ecologies' of connected games is closely related to the concept of polycentricity, which provides several theories that help to orient research in this field. The literature and its relation to research on connected games are briefly reviewed in Section 2.3.

2.1 Shared expectations and coordination

Subjective expected utility is a fundamental concept of decision theory. Although first axiomatized by von Neumann and Morgenstern in 1944 (Moscati 2019) and substantially revised and refined in recent decades, most notably with the development of prospect theory (Kahneman and Tversky 1979), the two basic components remain foundational. While the subjectivity of utility is long acknowledged, the subjectivity of expectations has received far less attention. In many decision-making situations, however, it is not only the preferences and utility that are subjective and may thus differ substantially among subjects, but also the expectations concerning the likelihood of future outcomes and the resulting expected utility of decisions (Mahoney 2004). This is especially the case under ambiguity (Knightian uncertainty), where probabilities of outcomes are unknown (Ellsberg 1961). Many economic decision environments are so complex that future outcomes are ambiguous, and the payoffs of strategies cannot be easily assigned to outcomes. Consequently, agents frequently need to choose between multiple ambiguous outcomes. Ambiguity aversion has received increasing attention in experimental research on individual decisions and games, and has been found to be context-dependent (Kocher et al. 2018; Kelsey and le Roux 2018). In situations with ambiguous outcomes, expectations may diverge considerably across agents. They may be shaped by diverging mental models (Denzau and North 1994), and the formation process and underlying models have received considerable attention in empirical research (D'Acunto and Weber 2024).

While there has been earlier work on the role of heterogeneous expectations in microeconomic empirical research (Manski 2004), the empirical foundation of expectations formation has received increasing attention in macroeconomics (D'Acunto and Weber 2024), especially since the 2007-08 global financial crisis. A whole economics handbook has recently been dedicated to expectations (Bachmann et al. 2023). Expectations have been shown to predict behavior in several different microeconomic domains and field settings, including expected income and education choices (Manski 2004), income and migration choices (McKenzie et al. 2013), coffee prices and labor allocation (Hill 2010) or monsoon onset and planting decisions (Giné et al. 2009), among others. Delavande et al. (2011) provide a review of this emerging research agenda in the field of development economics, while Armantier et al. (2013), Manski (2018), and D'Acunto and Weber (2024) provide a review in the field of macroeconomics.

The role of subjective expectations has also been studied in organizational economics. There is a long tradition of research on the behavioral theory of the firm, dating back to the 1930s (Mahoney 2004). This research tradition has long acknowledged that information processing regarding the outcomes of organizational choices may be limited and may deviate considerably from reality (March 1978). In situations with ambiguous outcomes, resulting expectations may remain subjective and heterogeneous. This research is most famously associated with the work of Herbert Simon and the notion of bounded rationality. While subjective expectations have received considerable attention in the behavioral and experimental literature, their role in industrial organization and institutional choice has remained underdeveloped. The first article in this thesis (see Section 3.1) addresses this research gap, while the three subsequent contributions focus on coordination problems and shared expectations (see Section 3.2, 3.3, and 3.4).

Heterogeneous subjective expectations, expectation formation processes, and related models have been extensively studied in the context of microeconomic individual decision-making situations and in agents' decisions within the context of macroeconomics, including savings and investment decisions, but also concerning multiple equilibria in macroeconomic models (Krugman 1991). The relevance of shared expectations within game theory has also been acknowledged for some time already for equilibrium selection in assurance games in the context of common-pool resource problems (Runge 1981), including the broader implications for economic development (Runge 1986; Kydd and Dorward 2004; Dorward et al. 2005).

The role of expectations in equilibrium selection has been further developed in the theory of collective action, building on empirical research on collective action and the assurance problem (Heckathorn 1996). More recently, the theory of collective action has been further refined by building on Schelling´s tipping games and focal points (Schelling 1978) and the concept of mixed strategy Nash equilibria (MSNE) (Medina Sierra 2007). Harsanyi and Selten (1988) proposed a theory for equilibrium selection in games based on MSNE, introducing the concept of stability sets and initial beliefs about the likely behavior of other players. This theory has been significantly advanced with epistemic game theory, where mixed strategies are treated as conjectures about other players' likely behavior (Aumann and Brandenburger 1995). By building on the method of stability sets and Schelling's focal point model for tipping games, where beliefs can initially be out of equilibrium, Medina Sierra (2007) proposed a theory of the process of collective action where expectations resulting from beliefs about other players´ behavior are crucial. My work on technology adoption, coordination failure, and shared expectations (see Section 3.2) builds on this idea and provides an empirical application. In parallel, this empirical research opens the door to the second major strand in the research literature of my habilitation thesis, which builds on the relevance of connected games.

The empirical case presented here (Section 3.2) is an example of two connected games, where a common-pool resource dilemma faces a dominant defection equilibrium and can only be resolved by coordinating on technology adoption in a connected coordination problem. In such cases, expectations in one game also depend on the expectations in connected games and are therefore correlated.

2.2 Coordination and connected games

Frequently, empirical cases of strategic interdependence are also characterized by multiple interdependent games. The outcome or strategy in one game affects one or multiple variables of another game. Which interdependencies exist in such connected games? How can these interdependent games be modelled?

The focus of large parts of the game theory literature is on models of generic, highly institutionalized, or otherwise structured situations. Normally, these situations are treated in isolation or extended to homogeneous games on graphs (Goyal 2007; Galeotti et al. 2010). However, there is also a growing body of literature that examines the variability of a situation due to changes in its institutional structure, which results from

connected situations and underlying games (McGinnis 2011). This institutional approach to studying networks of action situations has received considerable attention over the past decade (Kimmich et al. 2022).

According to reviews on this 'ecology of games' (McGinnis 2011; Kimmich et al. 2022), the first study to address multiple interrelated situations was conducted by sociologist Norton Long (1958), albeit in a non-formalized account. Two decades later, several more formal treatments appeared in the field of public choice on 'multistage games' (McKelvey and Niemi 1978), and later in the industrial organization literature on multimarket oligopolies (Bulow et al. 1985). In parallel, also the political sciences made use of this idea in the context of the two-arenas hypothesis of voting (Denzau et al. 1985), in 'nested games' (Tsebelis 1988), 'two-level games' (Putnam 1988), strategic issue linkage in international relations (McGinnis 1986), and the interdependence of monetary and fiscal policy and electoral games (Scharpf 1997). Physical connections and to the resulting inherent connectedness of games have also been addressed and illustrated in an application to the European gas trade, while also pointing at some implications for trade liberalization versus tariffs and cooperation in international monetary systems versus currency devaluation (Alt and Eichengreen 1989).

This work proposed systematic concepts for 'overlapping games' and 'parallel games.' Parallel games concern exclusive games among the same players, but in different arenas, whereas overlapping games are played against multiple other players, where strategies between games are interdependent. Overlapping games are a generalization of 'two-level' and 'nested games', which focus on the special cases of exclusive strategic interaction via an overlapping player in the 'two-level' case, and a specific sequence in the 'nested games' case. The idea and terminology of spillovers from choice go back to the analysis of multimarket oligopolies. Games with spillovers are inherently linked (Bulow et al. 1985).

The work by Alt and Eichengreen (1989) is not only seminal in the context of formalizing a theory of connected games, but it has also recently gained renewed empirical relevance with the war in Ukraine and the so-called trade wars (Fetzer and Schwarz 2021). Given the recent relevance, a brief illustration seems best with this example: In a security game, four EU countries participate in a public goods game of mutual defense (NATO), while in a gas trade game, two of these countries also compete with the Soviet Union to supply natural gas to EU countries. These games are overlapping. In the context of trade wars, the paper refers to cooperation among countries to liberalize

trade and supports the conclusion that large countries, which are central players in trade, are more likely to defect in trade liberalization.

The study of ecologies of games was also explored in the context of the regulation and governance of the telecommunications industry (Dutton and Mäkinen 1987), albeit with a less formal approach. This approach was later expanded to several other large technical systems and infrastructures (Dutton et al. 2012), including those that utilize social network analysis to capture multiple types of nodes (Cornwell et al. 2003). The most recent application, which employs a combination of qualitative and quantitative network analyses, aims to explain the German nuclear phase-out (Schneider 2025).

Roughly in the same time period when the first research on connected games emerged, the Popperian metatheory for situational analysis (Oakley 1999) led to a more generalized approach to game theory that was most clearly articulated in the work of Elinor Ostrom and co-authors. The systematic and parsimonious description of the institutional structure of games, as outlined in the Institutional Analysis and Development (IAD) framework (Ostrom et al. 1994), laid the foundation for a more formal study of the links between games and institutions (McGinnis 2011). My earlier work expanded on this institutional framework to also account for biophysical and informational links, as well as actor involvement, across games (Kimmich 2013a). Since then, at least 23 original research articles have been published that empirically studied the ecologies of games and related networks of action situations across a wide range of empirical applications (Kimmich et al. 2022). Most of these works have been largely qualitative with little formalization, owing to the complexity of such networks and the lack of standardized formal treatments.

A more formal approach has emerged on behavioral spillover across games and has been studied in evolutionary game theory and the so-called multiple games or game(s) theory approach, employing agent-based models (Bednar and Page 2007; Smaldino and Lubell 2011). This approach has recently also been studied more extensively in behavioral economics (Bednar et al. 2012; Engl et al. 2021).

Another increasingly systematic strand of research on the ecology of games has emerged from graph theory and social network analysis, establishing itself in the field of political science (Lubell 2013). Specifically, this approach uses bipartite graphs of agents connected to venues, related sub-graph network motifs, and statistical models for graphs to test hypotheses concerning collaboration in environmental resource governance. Since

its inception, these network-analytic methods have been extensively used in research on natural resource governance, including recent studies closely related to the institutional analysis of networks of action situations (Mewhirter et al. 2018; Lubell and Morrison 2021; Angst et al. 2022).

My own contributions to this field of research utilize stylized game theory models that are connected through spillovers from choice and spillovers resulting from the equilibrium outcomes of physically or institutionally connected games (Kimmich 2013a). The contributions to this thesis develop a more systematic study of networks of games (Kimmich and Sagebiel 2016; Kimmich and Villamayor-Tomás 2019) and propose the use of archetypal games in the study of connected games to keep the analysis of equilibrium outcomes tractable (Bruns and Kimmich 2021). The last article provides a systematic review of the empirical literature that has recently emerged in the field (Kimmich et al. 2022). The contributions are summarized in Section 3.

2.3 Polycentricity theory

Only three years after the idea of an 'ecology of games' was first developed by Norton Long (1958), a closely related ontology was proposed by Vincent Ostrom and colleagues, which they preliminarily termed 'polycentric political system' in search for a better term (Ostrom et al. 1961). Polycentricity meant that formally independent centers of decision-making could constitute an interdependent system with cooperative, contractual, or competitive relations. Public administration research frequently argued that such a governance of metropolitan areas by a multiplicity of overlapping political units was pathological, organized chaos, and that a centralized political unit ('gargantua'), would be more efficient in providing and producing public goods.

Several hypotheses concerning the efficiency, control, representation, and self-determination in polycentric systems were proposed, building on early public goods theory, externalities, and spillover effects. In their seminal empirical research, Elinor Ostrom and colleagues provided evidence that the polycentric provision and production of police services for law enforcement in smaller departments could actually be more efficient and effective than in larger police departments, while organizing specialized services on larger scales (Ostrom et al. 1973). More generally, Elinor Ostrom demonstrated that the scale of provision depends on the properties of the public good being provided. This was two decades before she demonstrated that the seeming tragedy

of the commons (Hardin 1968) did not require public or private ownership and that commons could be self-governed by their users (Ostrom 1990).

The Nobel Prize awarded to Elinor Ostrom in 2009, along with her related publication in the American Economic Review (Ostrom 2010a) and on the relevance of polycentric governance for climate change mitigation (Ostrom 2010b), led to increased attention to research on polycentricity. Aligica and Tarko (2012) reviewed earlier work on the concept by Polanyi, focusing on the social conditions that could preserve the rule of law and freedom of expression, and building on a long tradition that dates back to the work of French political philosopher Alexis de Tocqueville. Polanyi contrasted the concept of polycentricity with a socialist, monocentric system. The Ostroms developed an increasingly positive and precise theory, utilizing and extending public goods theory, along with an empirical research agenda to test polycentricity-related hypotheses (Aligica and Tarko 2012). Key recurring hypotheses suggest that polycentric systems are not only more effective and efficient, but also better at enabling cooperation, social learning, adaptation, and risk mitigation than monocentric, purely state- or market-governed systems (Ostrom 2010a; Goldthau 2014; Carlisle and Gruby 2017).

This foundation has been instrumental in advancing more positive theories of the structures and functions of polycentric systems, which also more clearly acknowledge some limitations of polycentric systems (Berardo and Lubell 2019; Baldwin et al. 2024). Although Elinor Ostrom made explicit that polycentric systems are no panacea, the theory remained normative, at least to the extent that it did not distinguish types or degrees of polycentricity. Polycentricity is now frequently defined as the coexistence of semi-autonomous centers of decision-making that overlap and are nested within multiple jurisdictions, whereas polycentric governance systems also consciously govern the relationships between these decision-making centers (Carlisle and Gruby 2017). Polycentric governance is occasionally contrasted with multilevel and purely decentralized governance, and can include hierarchies and networks, as described by Cumming (2016) in terms of heterarchies.

The political science literature and social network methods for polycentric systems predominantly study ‘policy games’ or forums and their interdependencies. The more detailed modelling of games and action situations that builds on economic science, game theory, and institutional analysis focuses more explicitly on the operational games, where polycentricity is normally the result of the biophysical and geospatial properties of

interdependent decisions, connected games, and the resulting industrial organization, rather than political governance. Some interdisciplinary and economic research also covers the interdependencies and interactions between collective choice and operational games explicitly (McGinnis 2011), including the biophysical and informational links between games (Kimmich 2013a). The focus is on analyzing the micro-situational interdependencies and interactions of connected games to test hypotheses concerning the effects of polycentric systems on equilibrium outcomes, but also considers some of their comparative advantages or weaknesses from an industrial organization perspective. Recurring hypotheses concern the role of coordination problems in relation to connected dilemmas or leverage points within such networks, which can induce spillover effects and change equilibrium outcomes in connected games. My work on connected games in Sections 3.5, 3.6, and 3.7 will focus on these aspects of polycentricity, contributing to a theory of polycentricity informed by the biophysical and institutional properties of operational situations and underlying games.

3 Contributions

The first article in this thesis (Kimmich and Fischbacher 2016) focuses on firm behavior, analyzing the effects of market price expectations on selling decisions and industrial organization. The dependent variable is the discrete structural alternative between make-or-buy decisions for harvesting and selling industrial round wood. The analysis employs an incentivized experiment to elicit price expectations from forest managers as subjects in a field experiment setting. The price elicitation is combined with an elicitation of risk preference and related uncertainty regarding the expected price. The analysis also takes into account the complementary roles of other behavioral variables, including time preference and trust (see Section 3.1).

Heterogeneous expectations are especially critical in collective decision-making. The second article (Kimmich and Sagebiel 2016) examines the role of shared expectations in a coordination problem related to technology adoption. Shared preferences are necessary for agreements on collective choices, but shared expectations may be at least as crucial as shared preferences (see Section 3.2).

In situations of collective choice, it becomes essential to facilitate the development of shared expectations, and shared mental models (Denzau and North 1994) may serve as an instrument to do so. The third article (Kimmich et al. 2019), therefore, develops a method to elicit expectations before and after a participatory modeling intervention to identify and test whether expectations have converged across subjects (see Section 3.3).

The fourth article synthesizes insights from the first three publications in the field of energy systems governance and energy transitions research. The development of expectations, including shared expectations for coordination and the importance of participatory modeling, is reviewed and illustrated for the case of the German renewable energy transition. The article also extends the approach to emphasize the importance of normative expectations in developing shared visions and the role of backcasting in this process (see Section 3.4).

A key insight of the article, summarized in Section 3.2, is that shared expectations also depend on connected games. The subsequent two research articles are contributions to advancing a more formal approach to the ecology of games that influence expectations and equilibrium outcomes in connected games. The fifth article builds on earlier work to develop a diagnostic procedure for tracing the cascading effects of equilibrium outcomes

across games connected by institutional, informational, and biophysical ties. This procedure helps identify which games' equilibrium shifts are necessary and which combinations are sufficient to resolve negative outcomes or maintain the robustness and resilience of Pareto-superior equilibrium outcomes in a focal game of interest to the researcher (see Section 3.5).

The sixth article develops a procedure for identifying game archetypes at different levels of abstraction, from an empirical context, to keep the analysis of connected games and networks tractable. The binary distinction between coordination and conflict problems may be too abstract, while a detailed model of each connected game with a specified number of players and production functions may be too specific and idiosyncratic. We propose three levels of primal and intermediate archetypes, building on the topology of 2x2 games with two players (see Section 3.6).

The last article presents a systematic literature review of research that employs the network approach to action situations to structure the analysis of connected games. This article concludes with a research agenda that could help to formalize the description of situation networks and modeling of connected games (see Section 3.7).

3.1 Expectations and supply chain governance (Kimmich and Fischbacher 2016)

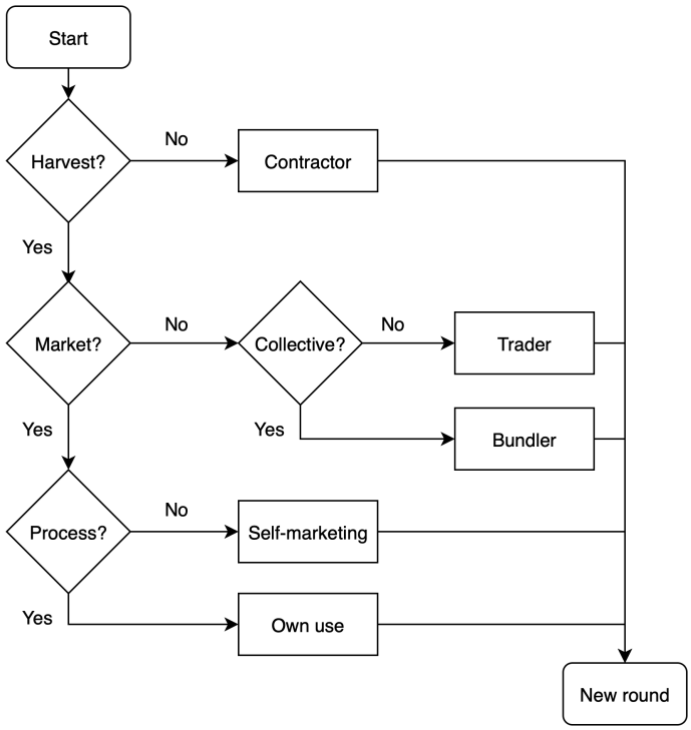
This article builds on institutional economics and the theory of the firm (Coase 1937; Klein et al. 1978; Williamson 1979; Grossman and Hart 1986) to examine the role that behavioral economics plays in explaining supply chain integration. The institutional theory of the firm explains why vertical integration exists when markets could also govern the same transactions. Transaction costs, asset specificity, and the frequency of transactions, as well as incomplete contracts, are crucial determinants of vertical integration. Here, we provide a theoretical framework and empirical support for the influence that individual behavior, including expectations, exerts on institutional choice.

The analysis focuses on the coexistence of vertically integrated and separated supply chains within a single industry, including the coexistence of both types at the firm level, referred to as plural forms (Bradach and Eccles 1989). Variation between firms cannot be explained by the physical properties of the goods and transactions alone if these are largely homogenous. Variation may therefore be influenced and caused by variation in managerial behavior.

The design employs four behavioral variables, including price expectations, risk and time preferences, and trusting behavior among supply chain agents, to explain the variation between firms in their supply chain choices, including the simultaneous use of vertically integrated and separated supply chains within firms. Four related hypothesis sets were derived and tested. The empirical context is the forestry industry and related roundwood supply chains in Switzerland. We employ context-adapted behavioral elicitation methods in a field experiment setting for each variable, using a sample size of 149 public forest managers from two Swiss cantons.

Figure 1 describes the decision logic for each forest unit in a flowchart. A forest manager can choose between four levels of vertical integration for harvesting, selling, and processing roundwood. The lowest level of integration is outsourcing the harvest and marketing directly to a contractor. At the highest level of integration, the forest manager markets the roundwood. A small fraction of forest managers also process roundwood, but this is only done for use in forest management.

Figure 1: Supply chain integration ("make or buy"). The flow chart communicates the key decision steps



The statistical models used in this article for fractional outcomes of allocated supply chain shares yield preliminary support for two hypotheses concerning price expectations. First, the more optimistic the price expectations, the more likely forest managers are to choose markets to sell roundwood. Second, the more patient, risk-averse, and pessimistic regarding prices, the more likely forest managers are to choose contractors and multiple supply chains simultaneously. The article suggests integrating behavioral theory into institutional economics and the theory of the firm to explain institutional choice, as standard behavioral assumptions are too unspecific to explain industrial organization.

3.2 Shared expectations and coordination (Kimmich and Sagebiel 2016)

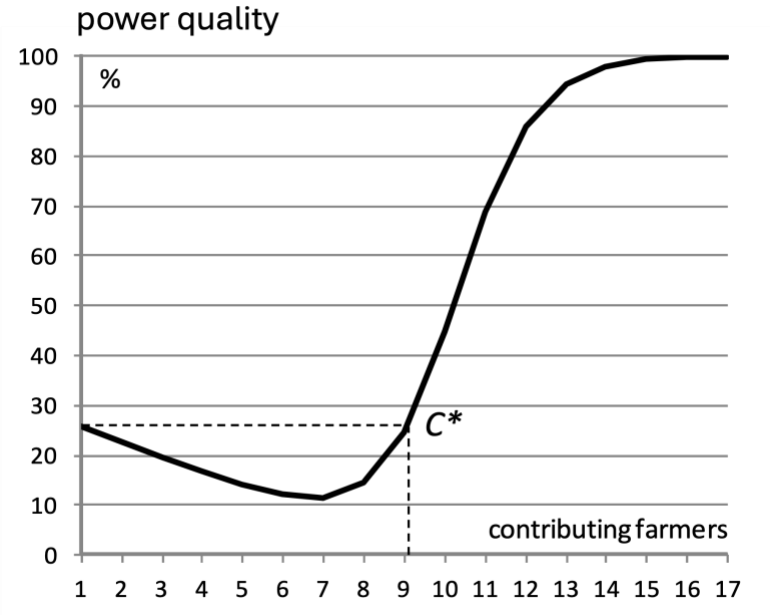
At the core of this article is an empirically motivated and parameterized game-theoretic model of two connected common-pool and threshold public good games related to electricity provision. The article demonstrates how shared expectations can resolve the common-pool resource dilemma of overexploiting electric infrastructure capacity through a connected coordination problem of technology adoption in a threshold public good problem related to electric power quality provision. While the common-pool

resource problem faces a dominant defection equilibrium, the connected coordination problem could change the payoff structure of the common-pool resource problem and help to resolve the dilemma. This, however, requires that shared expectations be developed that help to converge to the payoff-dominant equilibrium.

Building on common-pool resource theory (Ostrom et al. 1994), equilibrium selection theory of Harsanyi and Selten (1988) and the concept of mixed strategy Nash equilibria (MSNE), the chosen empirical case demonstrates, how the MSNE concept can be used to calculate the minimum expected payoff that is needed to surpass the bifurcation point above which each player´s strategy converges to the payoff-dominant equilibrium. The cut-off probability is calculated and compared with a biased belief about the coordination payoff and the extreme case of bounded rationality, where the players do not understand the coordination problem.

The empirical case concerns electricity provision for irrigation in India. Farmers use pumps to extract groundwater and irrigate their fields. The pumps are driven by electric energy and demand load from the electricity grid. Each additional load on the grid subtracts from the maximum capacity that the electricity grid can carry. Similarly, power quality is influenced by the type of electricity equipment connected to the grid. Farmers often use pumps of poor quality without capacitors, which can cause power quality issues in the electricity grid and result in a high frequency of burned pump motors. If farmers were to simultaneously invest in better equipment, including capacitors, then power quality would improve, and pump damage would occur more rarely (see Figure 4). In addition, the electricity grid could carry a higher load, and farmers would be more willing to contribute to public electricity infrastructure provision by authorizing their connection.

Figure 2: Production function for power quality with threshold



Survey data from a stratified random sample of 234 farmers are used to calculate the MSNE and to derive the rationality assumption needed to calculate the actual cut-off probability that divides the game into a payoff-dominant and a risk-dominant equilibrium. 85% of the farmers were unaware of the strategies employed by farmers connected to the same grid, revealing that the interdependence of decisions and the coordination problem are largely not understood. The vicious cycle could be transformed into a virtuous one by creating awareness and updating the beliefs about a coordinated payoff.

A key implication also concerns the effects of connected games on developing shared expectations. When coordination on the payoff-dominant equilibrium also increases the potential payoff in a connected game, then the expected payoff of coordination should be higher. More generally, this model demonstrates that accounting for such connected games is crucial to tracing the determining factors of equilibrium outcomes in more complex empirical settings. Section 3.5 builds on this insight and extends the model to other relevant games that affect payoff structures in the two connected games modeled here.

As part of a supervised Master's thesis, we also investigated the coordination problem of technology adoption in a framed field experiment, focusing on the effects of group size, leadership, and payoff structures (Müller et al. 2018). The experiment is based on a model that combines features of a step-level public good game and a critical mass game, which

most closely resembles the production function for electric power quality. We found that leading by example does not resolve the coordination problem, whereas smaller groups and higher payoffs led the subjects to be more likely to coordinate on the payoff-superior equilibria.

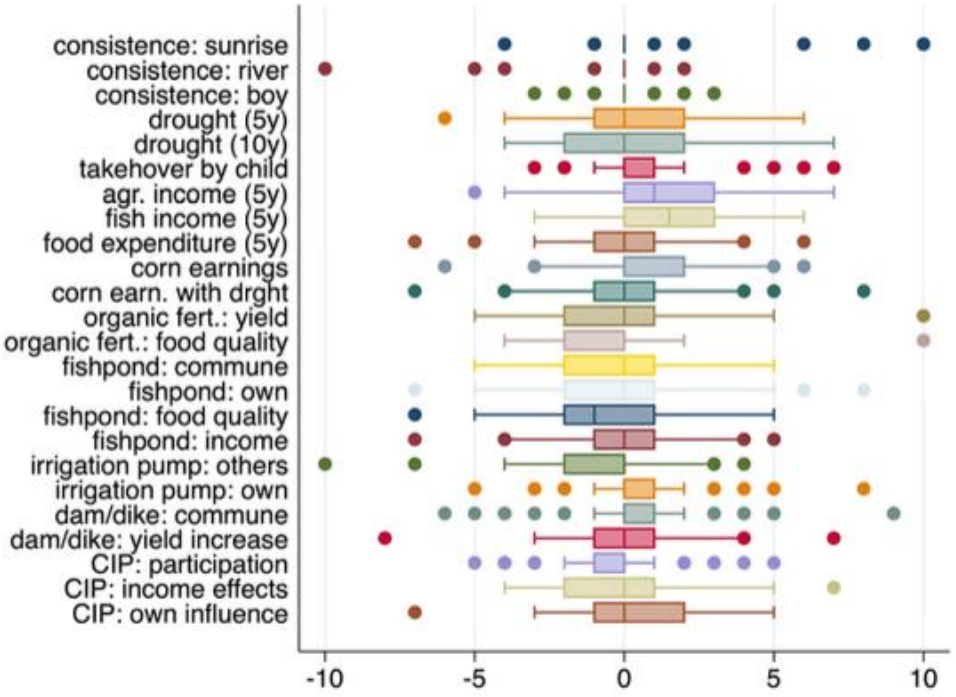
3.3 Shared expectations and participatory modeling (Kimmich et al. 2019)

Expectations play a crucial role in explaining individual and collective choices, as demonstrated by the two preceding studies. This article proposes a method for measuring changes in expectations to evaluate the effects of field interventions on individual and collective behavioral change. As behavioral change cannot be directly observed after intervention exercises, the immediate effects on changes in expectations may serve as an indicator of future behavioral change.

The application is a participatory modeling process, which is hypothesized to increase (1) individual agency via increasing optimism about outcomes that can be influenced by the participants and via (2) shared expectations that can increase the chances of collective action. The hypotheses build on the role of mental models (Denzau and North 1994; Rodrik 2014) and expectations in explaining behavior (Manski 2004; Jensen 2010; Delavande et al. 2011), including the role of shared expectations in collective action (Runge 1986).

The context in which this method is tested is a research project that focuses on participatory modeling of the water–energy–food nexus in the Mekong River Basin in Cambodia. The water–energy–food nexus is a functionally interdependent complex system, where high scientific uncertainty and low consensus on preferred interventions lead to situations of conflict. A set of expectation items concerning system outcomes under multiple scenarios is measured before and after participatory group modeling interventions in a field setting with fishing and farming community stakeholders.

Figure 3: Change in expected outcomes before and after intervention



Source: Kimmich et al. (2019)

The findings provide empirical support for the hypothesis that expectations concerning individual outcomes become more optimistic. The box plots in Figure 6 illustrate the changes in expectations before and after a participatory modelling intervention, where 0 denotes outcomes that are completely unlikely and 10 denotes outcomes that are completely certain. The first three items have been used to test whether the elicitation method has been understood. The variables related to agricultural and fishery income indicate that the expected probability has increased. We also find that expectations converge between participants across several system domains, as measured by a reduction in the standard deviation of each outcome variable, supporting the second hypothesis. Where expectations converge and outcomes are expected to be negative, the chances of collective action are likely to increase. The results also reveal where expectations diverge, indicating where system uncertainty requires further attention to develop a shared understanding of the system and expectations concerning simulation and scenario outcomes.

3.4 Energy modeling and normative expectations (Sgouridis et al. 2022)

This article builds on the previous three publications (Kimmich and Fischbacher 2016; Kimmich and Sagebiel 2016; Kimmich et al. 2019) and provides a synthesis for the context of energy modeling. The dimensions of coordination, shared expectations, and participatory modeling are applied to the renewable energy transition, and the roles of normative expectations and backcasting are introduced.

The coordination of investment decisions in the case of the Indian electricity grid depends on expected payoffs of the technology and the belief concerning the likelihood of others´ investment decisions. The more farmers invest, the higher the expected payoff. In a similar vein, the costs of renewable energy depend on the size of investments in these technologies. This is due to endogenous technological change, including learning-by-doing, economies of scale and scope, and related learning and experience curves. The more investments, the cheaper the technologies. The more countries invest, the faster the costs decline. The article concludes that a vision of the desired future is key before economic models can help to assess the economic implications of such a future.

3.5 Game networks in resource governance (Kimmich and Villamayor-Tomás 2019)

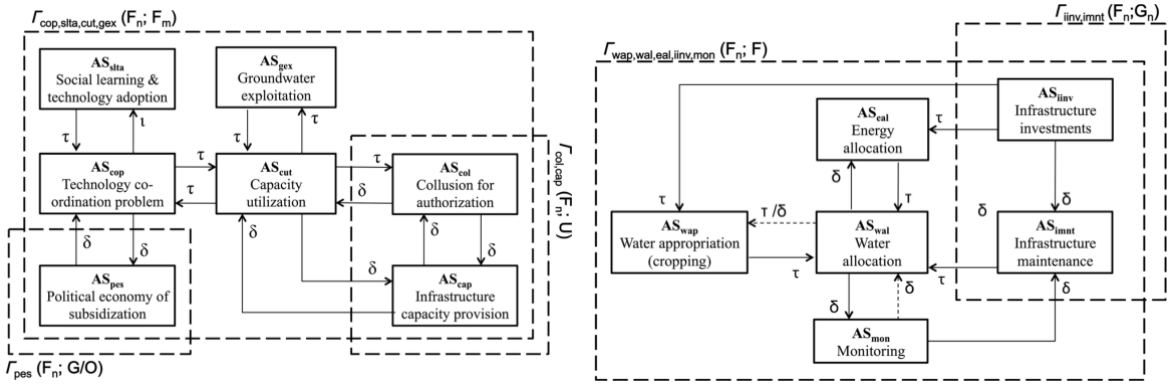
This article builds on Kimmich (2013a) and proposes a diagnostic procedure for networks of heterogeneous games. The structure of a game, including its institutional structure, is defined as an action situation (Ostrom et al. 1994). The key premise is that the equilibrium outcome of one game can influence the situational structure of a connected game (McGinnis 2011), by changing any of the seven structural game variables, including participants, positions (sequence), possible outcomes, action-outcome links, information, and available choices, payoff structures via four types of ties, including information, institutions, biophysical transactions, and agents involved (Kimmich 2013a).

The key objective of this article is to identify those games that need to be solved for a focal game´s positive equilibrium outcome to occur. Not all games in the network need to exhibit a Pareto-improving outcome to improve the outcome in the focal game. We propose a configurational causal procedure to identify which games and related game states (outcomes) are necessary and which configurations of games and game states are sufficient to result in positive focal outcomes. The method builds on set theory, which is used for configurational analyses (Ragin 2014). The procedure is then compared with a

degree centrality measure to test whether the more central games are also the necessary or even sufficient games to be addressed.

The diagnostic procedure is applied to two empirical cases with which the authors are most familiar, having previously published work on these cases. One is the Indian water–energy nexus case presented above, which features a persistent low equilibrium trap (see Section 3.2), whereas the other is a Spanish water–energy nexus case of a robust system that has remained persistently resilient to climate shocks.

Figure 4: Two game networks in water–energy–food nexus governance



Source: adaptation based on Kimmich and Villamayor-Tomás (2019)

For each case, selected configurations and related scenarios are presented and discussed. The article demonstrates that certain situations are critical and that related game states are necessary in each scenario. Both lateral and central games can have a significant impact on the network and focal game outcomes.

3.6 Game archetypes for the ecology of games (Bruns and Kimmich 2021)

A key challenge of modelling and analyzing larger networks of connected heterogeneous games is the resulting reduced tractability of the complex global game structures. In the preceding article, I have employed network-analytic methods to trace the cascading effects of equilibrium shifts in connected, but highly simplified, games of coordination and conflict. This approach is related to the models of games on graphs (Goyal 2007; Galeotti et al. 2010; Jackson and Zenou 2015). Here, the focus is on proposing a procedure to reduce the complexity of games to a level that can be used to model and handle all relevant situations in a network, thereby increasing the tractability of the resulting global game.

The paper builds on archetype analysis, an approach that I have been co-developing as a member of a larger interdisciplinary research network (Eisenack et al. 2019; Oberlack et al. 2019). Archetypes are recurring patterns and building blocks that help explain empirical phenomena using models at intermediate levels of abstraction, thereby avoiding the idiographic trap of highly detailed, yet case-specific, models on the one hand, and the nomothetic trap of overgeneralization with highly abstract models on the other.

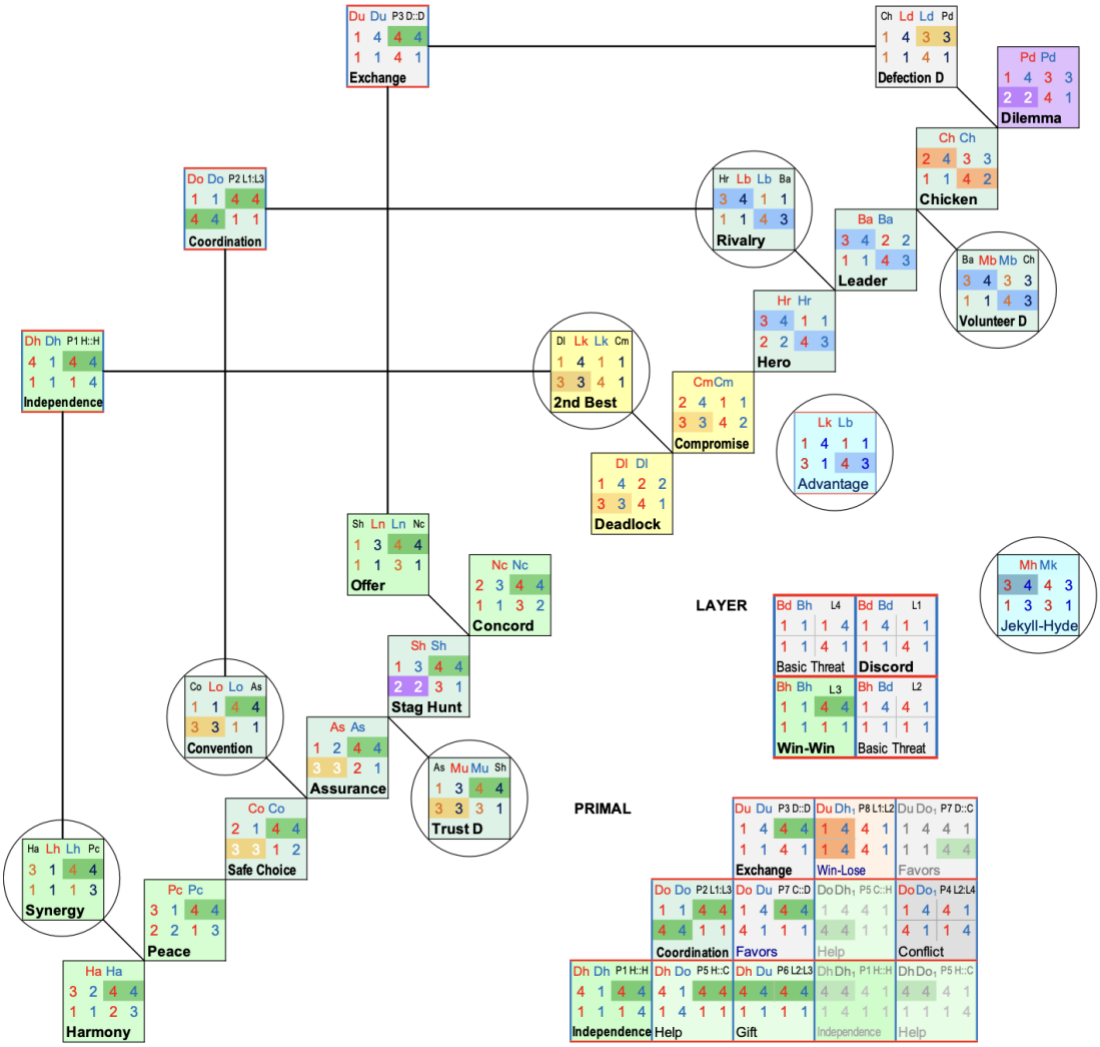
In game theory, the idea of proposing archetypes goes back to work by Anatol Rapoport (1967), who originally proposed four archetypal game models (Exploiter, Leader, Hero, and Martyr), where the last one is also known as the Prisoner´s Dilemma. The problem of risk-dominant equilibria in assurance problems was not recognized, but multiple asymmetric games were also neglected in this original work. In fact, the Prisoner´s Dilemma became the predominant model to explain cooperation in virtually any situation, to the extent that other models had been largely ignored for several decades. This has been the case in law (McAdams 2009), international cooperation (Snidal 1985), cooperation in climate mitigation (Pittel and Rübbelke 2012; Aklin and Mildenberger 2020), environmental conservation (Curry et al. 2019), macroeconomics and social discounting (Sen 1967), and many other fields (Skyrms 2004). The exploitation of common-pool resources has also been equated with the Prisoner´s Dilemma (Cole and Grossman 2010), even though alternative models had been proposed early on (Runge 1981). In many cases, assurance models are more appropriate.

The neglect of many empirically relevant models led to several more eclectic game model selections in the literature, which is also the case for many textbooks used in introductory courses on game theory. A key contribution to systematic game selection was the empirically informed selection of relevant game models in social psychology (Kelley et al. 2003). Another approach was to systematically develop and study the topology of games (Robinson and Goforth 2005).

We propose and develop a deductive approach to simplify games by systematically making and breaking ties in the payoff structures of all elementary 2x2 games in the topology of ordinal games with four payoff ranks. The procedure of making ties in the four ordinal payoffs to reduce the payoff structure to two ordinal payoff levels helps to derive three symmetric primal archetypes of exchange, coordination, and independence, which can be combined to generate three asymmetric primal archetypes of dependence, power, or conflict, and, with different forms of asymmetry in dependence, further differentiated

into eight primal archetypes. By stepwise breaking ties in the payoff ranks, these primal archetypes can be differentiated into archetypes with middle ties and intermediate archetypes to model situations of advantage, rivalry, conventions, compromise, or synergy (see Figure 7).

Figure 5: Archetypal games



Source: Bruns and Kimmich (2021)

We discuss the relationships between game archetypes and organizational archetypes, as well as systems archetypes. Note that many asymmetric games have only very recently received increasing attention, including experimental laboratory studies (Hauser et al. 2019; Nockur et al. 2020), but are likely far more common in the field than symmetric games. This is also the case for the recently renewed attention to power relations, which we discuss in relation to asymmetric archetypal games. Most importantly, however, in the

context of connected games, the primal and intermediate archetypes provide two major benefits: first, they help systematically identify the structure of each situation relevant in an empirical context, and second, they model simple connected games so that the global structure remains tractable.

3.7 Systematic review on networks of action situations (Kimmich et al. 2022)

The diversity of empirical cases leads us back to the broader situational and institutional analysis that helps to structure games and has been briefly described in the literature review in Section 2.2. While Popper conceptualized situational analysis mainly for economics (Oakley 1999), there have also been influential proposals in political science (Farr 1985; Scharpf 1997) and in the social sciences more broadly (Matzner and Bhaduri 1998). These contributions, particularly the close and interdisciplinary collaboration between Elinor Ostrom and Reinhard Selten (Kliemt 2011; Erickson 2024), led to an integrative framework of situational analysis for the social sciences, drawing on game theory and institutional economics (Ostrom et al. 1994). The objective was to develop a parsimonious framework that describes all necessary and relevant variables to specify game models of situations, with a special focus on common-pool resource exploitation dilemmas. The framework has been widely applied across various domains and disciplines, as a recent review demonstrates (Schlager and Villamayor-Tomas 2023). Many empirical applications focus on isolated situations and games; however, they often miss potentially influential factors that originate from connected games. The only exception was research that considered the distinction and interactions between operational, collective, and constitutional choice (Ostrom 2005). This led to the proposal of extending situational analysis to networks of adjacent action situations (McGinnis 2011), which account for institutional, informational, as well as biophysical links between situations (Sendzimir et al. 2010; Kimmich 2013a).

Multiple empirical applications followed, which led to a discussion on how to accumulate knowledge for a more systematic and formal analysis of situation-centered network analysis. This culminated in a review that I have been leading together with experienced scholars in the field. Our review found that, since the first conceptualizations of networks of action situations, more than 23 empirical applications had been published by 2022 that explicitly analyze multiple action situations and the links among them. The applications range from natural resource and related technology and infrastructure

governance, including river basins, water infrastructure, and irrigation; energy infrastructure, oil, gas pipelines, and renewable energy governance; agriculture and food systems, biodiversity, landscapes, and marine resources; to questions related to urbanization or tourism, but also childcare and public service delivery. The approach appears to be particularly prevalent in cross-sector analyses, as evidenced by more than half of the studies.

We found that the most frequent network size included between five to seven action situations. All studies covered interactions between operational and collective choice, but only three extended their analysis to the constitutional choice level. Most articles employed thick description and figures, including directed graphs with situation nodes, but used almost no formal models or quantitative methods. Only three studies employed game-theoretic models, and one study used set theory to analyze configurations of outcomes across situations (see Section 3.5).

The review also compares situation-centered network analysis with social network analysis of actors participating in collective choice situations, building on bipartite graphs where two types of nodes—actors and venues—and ties between these are modeled (see Section 2.2). Unlike the study of connected games, this approach abstracts from both the dynamics resulting from the choices and strategies of actors in situations, as well as from the effects that one strategy or equilibrium outcome can have on the variables of a connected game. The focus is also exclusively on collective choice situations, also referred to as policy institutions, venues, or planning processes in this literature (Lubell 2013). The situation-centered approach to networks of action situations, on the other hand, where situations can be directly linked, would translate into multilevel and multiplex networks (Gómez-Gardeñes et al. 2012). Both approaches, however, are instrumental to advancing research on polycentricity and related theories.

4 Discussion

The discussion reflects on the three major directions for theory contributions in each literature reviewed in Section 2, starting with polycentricity theory (Section 2.3), which the last three articles referred to, followed by a discussion on modelling connected games (Section 2.2), and completed by a discussion of the role of expectations (Section 2.1).

4.1 Advancing polycentricity theory

Research on polycentricity across disciplines can be differentiated into spatial, political, organizational, and operational polycentricity. A major body of research focuses on the spatial polycentricity of overlapping political and operational units across jurisdictions. Research on spatial polycentricity made important contributions to public administration and public economics, starting with the original contributions on public goods provision in metropolitan areas (Ostrom et al. 1961). Another research strand focuses on organizational polycentricity of political governance (Baldwin et al. 2024). The social network analysis of actors and policy forums has a strong focus on this dimension (Lubell 2013).

A key concern from an economic perspective is the governance of public and private provision of goods via markets, states, and other forms of organization (Ostrom 2010a). In this context, economic theory on polycentricity has a stronger focus on the operational choice level and is closely related to the theory of the firm, industrial organization, and institutional economics. The key question, whether transactions are better organized via markets, hierarchies, or hybrid forms (Ménard 2004; Künneke et al. 2010), needs to be augmented by considering multiple interdependent transactions.

The biophysical and functional interdependence of transactions necessitates coordination and integrative institutions, whereas modularity facilitates the operational separation of decision centers (Hagedorn 2008). The first article of this thesis (Kimmich and Fischbacher 2016) provides an empirical example of multiple transactions (harvesting, marketing, processing) that are largely modular and can be integrated or outsourced to different types of supply chain partners, including contractors and traders (see Section 3.1). Conversely, empirical examples of connected games (Kimmich and Sagebiel 2016; Kimmich and Villamayor-Tomás 2019) demonstrate functional interdependence and necessitate coordination across games for efficient and effective governance.

The interdependencies in connected games at the operational level indicate effective and efficient types of polycentricity that provide an institutional fit for the biophysical properties of the economic resource, infrastructure, or public good being studied. Coordination problems and spillovers across games can be revealed, as well as leverage points that change equilibrium outcomes in polycentric systems (see Sections 3.5 and 3.7).

4.2 Modelling connected games

The most fundamental challenge concerns the development of formal methods and models to analyze connected games. As revealed by the systematic review, most published research on networks of action situations employs qualitative methods and has been far less formal than research in game theory in general. Formal analysis of ecologies of games is constrained by the complexity of connected games. There have been pragmatic proposals for approximating tractable models to cope with such complexity (Scharpf 1990), but there has also been a call for solutions that can capture complex systems early on (Bennett 1991). Progress in this direction, however, has only been made in recent years.

One promising research direction has been made possible with the development of compositional game theory (Ghani et al. 2018). This progress is comparable to the transition from linear to object-oriented programming and the advancement of agent-based models in economics (Tesfatsion and Judd 2006). While classical game theory could, in principle, handle multiple linked games in one game tree, such a tree would grow exponentially. Conversely, compositional game theory utilizes the concept of open games, derived from category theory, to model games with inputs and outputs from connected games, thereby maintaining tractability through the use of string diagrams (Frey et al. 2023).

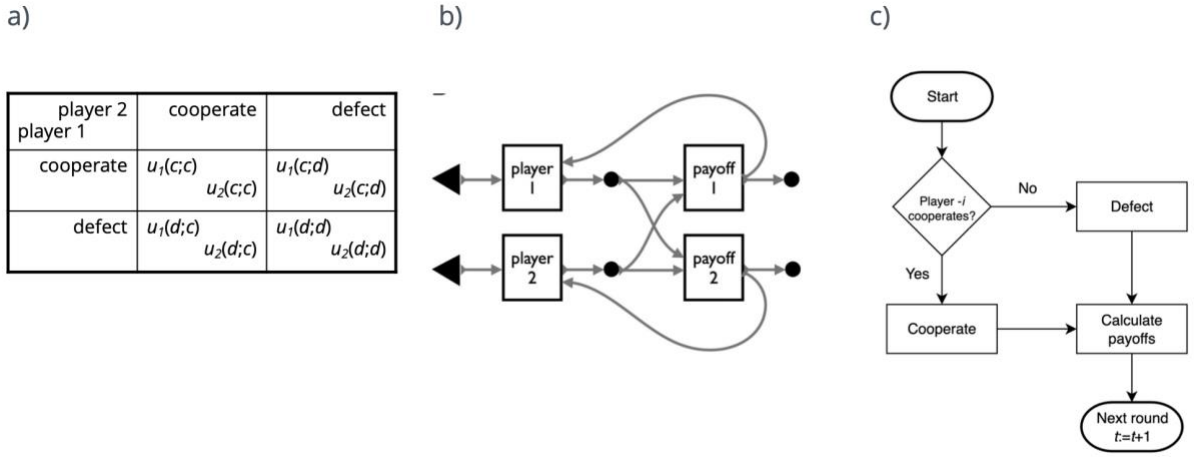
This approach has the potential to help formalize research on linked games and can capture both parallel and sequential game structures. Many empirical applications, however, face connected games in linked situations where interdependence is more complex. Connected games may not only affect payoffs, but also available choices and institutions, or even player involvement. Connected games may also exhibit bidirectional causation, and the frequency of game repetition may be asynchronous or even endogenous (Kimmich 2013a). In such cases, the use of situational network approaches and agent-based models may be the only operational solutions.

This leads us to the second promising research direction. Agent-based models have already been used to model selected operational-choice situations and games; however, an integration of collective-choice situations has also been implemented (Smajgl et al. 2008). Agent-based models can capture spatial dynamics, behavioral spillovers, network effects, and extend general equilibrium to the biophysical and political domain. More fundamentally, agent-based models also consider out-of-equilibrium dynamics, including

cycles, bifurcations, and emergence. Conversely, the explicit integration of deductive game theory into agent-based models has the potential to guide the development of agent-based models and inform solution concepts (de Marchi and Page 2014). This combination can be extended to connected games with heterogeneous game structures and ties between games.

Figure 7 provides a stylized distinction between the basic structure of a matrix game (a), a compositional open game description via string diagrams (b) (Frey et al. 2023), and a flow chart that can be used to communicate agent algorithms in agent-based models (c) (Müller et al. 2014). String diagrams offer an intuitive modeling structure for capturing spillovers and feedback across games. The focus on equilibrium selection remains. Conversely, agent-based models must be explicit about the agent's behavior, strategy selection, and the underlying process. The famous Prisoner´s Dilemma computer tournaments are a good example (Axelrod and Hamilton 1981).

Figure 6: Basic bimatrix games, compositional games, and agent-based models



More generally, the institutional description of situations and underlying games can be used to systematically develop agent-based models. The Institutional Analysis and Development (IAD) framework—a cornerstone of situational analysis—has been used and proposed to structure the programming of agent-based models (Ghorbani et al. 2013). The framework was originally developed to systematically describe the structure of situations for a translation into game-theoretic models (Ostrom et al. 1994) and has long demonstrated its potential in empirical research on natural resource and public goods governance (Ostrom 2010a). In a recent article on extending the Networks of Action Situations (NAS) framework, we have implemented a procedure for capturing the

ecology of games in an agent-based model of cap-and-trade land-use governance in China (Tan et al. 2023).

The IAD framework has also been recently utilized to define a language for action situations and to develop a game engine and software that can automatically generate extensive form game-theoretic models from descriptions covering any of the variables defined in the IAD framework (Montes et al. 2022).

There is also a growing body of research in computer science on computational, algorithmic, or empirical game theory, which places a stronger emphasis on empirical methods, including simulation, machine learning, and evolutionary processes (Wellman et al. 2025). With the rise of empirically oriented game theory across disciplines, including areas such as artificial intelligence and cybersecurity (Wellman et al. 2025), compositional game theory and the ecology of games approach will become increasingly relevant to a broader range of disciplines.

Future research on the broader situational analysis of multiple, linked action situations can help advance our understanding of more complex governance mechanisms. This research agenda can leverage the common language and institutional analysis frameworks that have been developed to facilitate collaboration across game theory, behavioral and experimental economics, and other social science disciplines and methods (Poteete et al. 2010). The unification of the social and behavioral sciences through game theory (Gintis 2009) is facilitated by a broader framework, such as the IAD and NAS frameworks, which enable interdisciplinary research and the accumulation of knowledge.

4.3 Facilitating shared expectations

The emphasis on process and out-of-equilibrium dynamics in agent-based models is also relevant in the context of coordination problems. The original theory of equilibrium selection, based on MSNE (Harsanyi and Selten 1988), proposes a tracing procedure that utilizes stability sets and initial beliefs to identify payoff-dominant and risk-dominant equilibria. Inspired by this theory and focal points in tipping games, Medina Sierra (2007) developed a theory that focuses on the process of collective action, where the MSNE describes the bifurcation between the Pareto-superior and inferior equilibria. In the process, initial beliefs about the likely strategy of others can be influential in progressing towards coordination or coordination failure. Yet, updating beliefs and related

expectations early in the process can also facilitate a change in the unfolding trajectory of the collective action equilibrium. Process matters.

The empirical research on expectations in coordination problems in this thesis (Section 3.2) is an example where coordination failures occur due to ambiguity and bounded rationality, even when the payoffs of coordination are significantly higher than in the low equilibrium. The empirical case also demonstrates how a physically connected game can influence equilibrium outcomes in a coordination problem, and vice versa.

Inspired by the idea of shared mental models (Denzau and North 1994) and the participatory modeling literature (Voinov et al. 2016), the next step was to test whether a participatory modeling process leads to convergence in expectations in an empirical context of a complex system with scientific uncertainty and low consensus, thereby assessing the potential for shared expectations and collective action (Section 3.3).

These insights laid the foundation for contributing to a publication on the role that energy models, expectations, and normative visions play in the energy transition (Section 3.4). With learning-by-doing and economies of scale of renewable energy adoption, model scenarios also become subject to endogenous technological change. The resulting uncertainty of model predictions is also reflected in ambiguous expectations, due to their scenario dependence. In such a context, the role of normative expectations and visions becomes important, not only to explain likely future transition paths, but also to facilitate backcasting processes.

5 Conclusion

This thesis is guided by two overarching questions: first, concerning the role of expectations in industrial organization and collective action for the provision of public goods and natural resource governance, and second, concerning the role of interdependencies between connected games in common-pool resource and infrastructure governance. The thesis builds on three strands of literature: (1) behavioral and experimental economic research on expectations, (2) the growing body of research on connected games, the ecology of games, and networks of action situations, and (3) the overarching theories of polycentricity in economic and political governance, with a focus on public goods and natural resource governance.

Starting with the role of heterogeneous individual expectations in industrial organization, the thesis expands to the role of shared expectations in coordination problems, the effects of participatory modelling on shared expectations, and the role of normative expectations in energy policy. The role of connected games in shared expectations also pointed to the relevance of expanding empirical research on natural resources, public goods, and infrastructure governance from focal, isolated games to adjacent, connected games and larger ecologies and networks of games. The thesis contributes to this research agenda through empirical research on connected games and networks of action situations, a proposal to utilize game archetypes when modeling networks of action situations, and a systematic review of the empirical research that has increasingly been able to capture the complexity of such networks over the last two decades.

Shared expectations are fundamental preconditions in complex, multi-actor networks of action situations, as the move towards participatory research demonstrates. In this process, scenario analysis also plays a key role in facilitating shared expectations (Swart et al. 2004). The probability of different scenarios has become an increasing concern, especially in the integrated assessment literature on climate change (Morgan and Keith 2008; Ho et al. 2019; Hausfather and Peters 2020; Schwalm et al. 2020). At the same time, ambiguity in climate change models has also received increasing attention (Millner et al. 2013). Where political decisions significantly impact scenarios, uncertainty and ambiguity increase considerably, and reducing ambiguity becomes crucial in the policy process (Cairney et al. 2016). This has also led to the creation of prediction markets and polls to aggregate individual expectations (Atanasov et al. 2016; Tetlock et al. 2017).

Enabling shared expectations is also a key contribution of macroeconomic research. My recent article on the impact of macroeconomic climate on adaptation research is, among others, also a contribution to this endeavor (Kimmich et al. 2025). At the science–policy interface, however, it is not only the facilitation of shared expectations based on scientific evidence that matters, but also an understanding of the action situations and decision-makers relevant to the issue (Cairney et al. 2016). Research on the networks of action situations and the dynamics of connected games has the potential to contribute to this progress.

6 Authorship contribution

Whereas the doctoral thesis consisted of three peer-reviewed single-author articles (Kimmich 2013a, b, 2016) and a monography (Kimmich 2013c), the publications presented in this commentary have all been written with co-authors. The following Table 2 provides a list of all articles that form part of this thesis, including author roles and position, and the contribution share in each publication.

	Title	Authors	Contribution
1	Behavioral determinants of supply chain integration and coexistence	2, lead author	90%: conceptualization, methodology, data curation, analysis, visualization, writing – original draft, writing – review & editing
2	Empowering irrigation: A game-theoretic approach to electricity utilization in Indian agriculture	2, lead author	90%: conceptualization, methodology, survey design, data collection, analysis, writing – original draft, writing – review & editing
3	Participatory modelling updates expectations for individuals and groups, catalyzing behavior change and collective action in nexus governance	7, lead author	50%: conceptualization, methodology, data curation, formal analysis, validation, visualization, writing – original draft, writing – review & editing
4	Visions before models: The ethos of energy modeling in an era of transition	6, second author	15%: conceptualization, writing – original draft, writing – review & editing
5	Assessing action situation networks: a configurational perspective on water and energy governance in irrigation systems	2, lead author	70%: conceptualization, methodology, formal analysis, visualization, writing – original draft, writing – review & editing
6	Archetypal games generate diverse models of power, conflict, and cooperation	2, second author	30%: conceptualization, methodology, validation, writing – original draft, writing – review & editing
7	Networks of action situations: a systematic review of empirical research	5, lead author	50%: conceptualization, methodology, data curation, formal analysis, validation, visualization, writing – original draft, writing – review & editing

Table 2: Thesis articles, author role, and author contributions

References

Aklin M, Mildenberger M (2020) Prisoners of the wrong dilemma: why distributive conflict, not collective action, characterizes the politics of climate change. Glob Environ Polit 20:4–27

Aligica PD, Tarko V (2012) Polycentricity: From Polanyi to Ostrom, and Beyond. Governance 25:237–262. https://doi.org/10.1111/j.1468-0491.2011.01550.x

Alt JE, Eichengreen B (1989) Parallel and overlapping games: Theory and application to the European gas trade. Econ Polit 1:119–144. https://doi.org/10.1111/j.1468-0343.1989.tb00008.x

Angst M, Mewhirter J, McLaughlin D, Fischer M (2022) Who Joins a Forum—And Who Does Not?—Evaluating Drivers of Forum Participation in Polycentric Governance Systems. Public Adm Rev 82:692–707. https://doi.org/10.1111/puar.13427

Armantier O, Bruine de Bruin W, Potter S, et al (2013) Measuring Inflation Expectations. Annu. Rev. Econ. 5:273–301

Atanasov P, Rescober P, Stone E, et al (2016) Distilling the Wisdom of Crowds: Prediction Markets vs. Prediction Polls. Manag Sci 63:691–706. https://doi.org/10.1287/mnsc.2015.2374

Aumann R, Brandenburger A (1995) Epistemic Conditions for Nash Equilibrium. Econometrica 63:1161–1180. https://doi.org/10.2307/2171725

Axelrod R, Hamilton WD (1981) The evolution of cooperation. Science 211:1390–1396. https://doi.org/10.1126/science.7466396

Bachmann R, Topa G, van der Klaauw W (2023) Preface. In: Bachmann R, Topa G, van der Klaauw W (eds) Handbook of Economic Expectations. Academic Press, pp xxv–xxvi

Baldwin E, Thiel A, McGinnis M, Kellner E (2024) Empirical research on polycentric governance: Critical gaps and a framework for studying long-term change. Policy Stud J 52:319–348. https://doi.org/10.1111/psj.12518

Bednar J, Chen Y, Liu TX, Page S (2012) Behavioral spillovers and cognitive load in multiple games: An experimental study. Games Econ Behav 74:12–31. https://doi.org/10.1016/j.geb.2011.06.009

Bednar J, Page S (2007) Can Game(s) Theory Explain Culture? Ration Soc 19:65–97. https://doi.org/10.1177/1043463107075108

Bennett PG (1991) Modelling Complex Conflicts: Formalism or Expertise? Rev Int Stud 17:349–364

Berardo R, Lubell M (2019) The Ecology of Games as a Theory of Polycentricity: Recent Advances and Future Challenges. Policy Stud J 47:6–26. https://doi.org/10.1111/psj.12313

Bradach JL, Eccles RG (1989) Price, Authority, and Trust: From Ideal Types to Plural Forms. Annu Rev Sociol 15:97–118. https://doi.org/10.1146/annurev.so.15.080189.000525

Bruns B, Kimmich C (2021) Archetypal games generate diverse models of power, conflict, and cooperation. Ecol Soc 26:. https://doi.org/10.5751/ES-12668-260402

Bulow JI, Geanakoplos JD, Klemperer PD (1985) Multimarket Oligopoly: Strategic Substitutes and Complements. J Polit Econ 93:488–511. https://doi.org/10.1086/261312

Cairney P, Oliver K, Wellstead A (2016) To Bridge the Divide between Evidence and Policy: Reduce Ambiguity as Much as Uncertainty. Public Adm Rev 76:399–402. https://doi.org/10.1111/puar.12555

Carlisle K, Gruby RL (2017) Polycentric Systems of Governance: A Theoretical Model for the

Commons. Policy Stud J 0: https://doi.org/10.1111/psj.12212
Coase RH (1937) The Nature of the Firm. Economica 4:386–405. https://doi.org/10.1111/j.1468-0335.1937.tb00002.x
Cole DH, Grossman PZ (2010) Institutions matter! Why the Herder Problem is not a Prisoner's Dilemma. Theory Decis 69:219–231. https://doi.org/10.1007/s11238-008-9121-3
Cornwell B, Curry TJ, Schwirian KP (2003) Revisiting Norton Long's Ecology of Games: A Network Approach. City Community 2:121–142. https://doi.org/10.1111/1540-6040.00044
Cumming GS (2016) Heterarchies: Reconciling Networks and Hierarchies. Trends Ecol Evol 31:622–632. https://doi.org/10.1016/j.tree.2016.04.009
Curry OS, Hare D, Hepburn C, et al (2019) Cooperative conservation: Seven ways to save the world. Conserv Sci Pract n/a:e123. https://doi.org/10.1111/csp2.123
D'Acunto F, Weber M (2024) Why Survey-Based Subjective Expectations Are Meaningful and Important. Annu. Rev. Econ. 16:329–357
de Marchi S, Page SE (2014) Agent-Based Models. Annu. Rev. Polit. Sci. 17:1–20
Delavande A, Giné X, McKenzie D (2011) Measuring subjective expectations in developing countries: A critical review and new evidence. J Dev Econ 94:151–163. https://doi.org/10.1016/j.jdeveco.2010.01.008
Denzau A, Riker W, Shepsle K (1985) Farquharson and Fenno: Sophisticated voting and home style. Am Polit Sci Rev 79:1117–1134
Denzau AT, North DC (1994) Shared Mental Models: Ideologies and Institutions. Kyklos 47:3–31. https://doi.org/10.1111/j.1467-6435.1994.tb02246.x
Devetag G, Ortmann A (2007) When and why? A critical survey on coordination failure in the laboratory. Exp Econ 10:331–344. https://doi.org/10.1007/s10683-007-9178-9
Dorward A, Kydd J, Morrison J, Poulton C (2005) Institutions, Markets and Economic Co-ordination: Linking Development Policy to Theory and Praxis. Dev Change 36:1–25. https://doi.org/10.1111/j.0012-155X.2005.00400.x
Dutton WH, Mäkinen H (1987) The development of telecommunications: The outcome of an ecology of games. Inf Manage 13:255–264
Dutton WH, Schneider V, Vedel T (2012) Ecologies of Games shaping Large Technical Systems: Cases from Telecommunications to the Internet. In: Bauer J, Lang A, Schneider V (eds) Innovation Policy and Governance in High-Tech Industries: The Complexity of Coordination. Springer, Berlin, Heidelberg, pp 49–75
Eisenack K, Villamayor-Tomas S, Epstein G, et al (2019) Design and quality criteria for archetype analysis. Ecol Soc 24:
Ellsberg D (1961) Risk, Ambiguity, and the Savage Axioms*. Q J Econ 75:643–669. https://doi.org/10.2307/1884324
Engl F, Riedl A, Weber R (2021) Spillover Effects of Institutions on Cooperative Behavior, Preferences, and Beliefs. Am Econ J Microecon 13:261–99. https://doi.org/10.1257/mic.20180336
Erickson P (2024) Bielefeld Game Theory and Indiana Institutional Analysis: Elinor Ostrom and Theories of Common-Pool Resources. Hist Polit Econ 56:537–560. https://doi.org/10.1215/00182702-11156184
Farr J (1985) Situational Analysis: Explanation in Political Science. J Polit 47:1085–1107. https://doi.org/10.2307/2130808
Fetzer T, Schwarz C (2021) Tariffs and Politics: Evidence from Trump's Trade Wars. Econ J 131:1717–1741. https://doi.org/10.1093/ej/ueaa122
Frey S, Hedges J, Tan J, Zahn P (2023) Composing games into complex institutions. Plos One 18:e0283361
Galeotti A, Goyal S, Jackson MO, et al (2010) Network Games. Rev Econ Stud 77:218–244.

https://doi.org/10.1111/j.1467-937X.2009.00570.x
Ghani N, Hedges J, Winschel V, Zahn P (2018) Compositional Game Theory. In: Proceedings of the 33rd Annual ACM/IEEE Symposium on Logic in Computer Science. Association for Computing Machinery, New York, NY, USA, pp 472–481
Ghorbani A, Dignum V, Bots P, Dijkema G (2013) MAIA: a framework for developing agent-based social simulations. JASSS- J Artif Soc Soc Simul 16:9
Giné X, Townsend R, Vickery J (2009) Forecasting when it matters: evidence from semi-arid India. Manuscr FRB NY
Gintis H (2009) The bounds of reason: game theory and the unification of the behavioral sciences. Princeton University Press, Princeton
Goldthau A (2014) Rethinking the governance of energy infrastructure: Scale, decentralization and polycentrism. Energy Res Soc Sci 1:134–140. https://doi.org/10.1016/j.erss.2014.02.009
Gómez-Gardeñes J, Reinares I, Arenas A, Floría LM (2012) Evolution of Cooperation in Multiplex Networks. Sci Rep 2:620. https://doi.org/10.1038/srep00620
Goyal S (2007) Connections: an introduction to the economics of networks. Princeton University Press, Princeton
Grossman SJ, Hart OD (1986) The costs and benefits of ownership: A theory of vertical and lateral integration. J Polit Econ 691–719
Hagedorn K (2008) Particular requirements for institutional analysis in nature-related sectors. Eur Rev Agric Econ 35:357–384
Hardin G (1968) The Tragedy of the Commons. Science 162:1243–1248. https://doi.org/10.1126/science.162.3859.1243
Harsanyi JC, Selten R (1988) A general theory of equilibrium selection in games. MIT Press, Cambridge, Mass.
Hauser OP, Hilbe C, Chatterjee K, Nowak MA (2019) Social dilemmas among unequals. Nature 572:524–527. https://doi.org/10.1038/s41586-019-1488-5
Hausfather Z, Peters GP (2020) Emissions–the 'business as usual'story is misleading. Nature 577:618–620
Heckathorn DD (1996) The Dynamics and Dilemmas of Collective Action. Am Sociol Rev 61:250–277
Hill RV (2010) Liberalisation and Producer Price Risk: Examining Subjective Expectations in the Ugandan Coffee Market. J Afr Econ 19:433–458
Ho E, Budescu DV, Bosetti V, et al (2019) Not all carbon dioxide emission scenarios are equally likely: a subjective expert assessment. Clim Change 155:545–561. https://doi.org/10.1007/s10584-019-02500-y
Isaac RM, Schmidtz D, Walker JamesM (1989) The assurance problem in a laboratory market. Public Choice 62:217–236. https://doi.org/10.1007/BF02337743
Jackson MO, Zenou Y (2015) Chapter 3 - Games on Networks. In: Young HP, Zamir S (eds) Handbook of Game Theory with Economic Applications. Elsevier, pp 95–163
Jensen R (2010) The (perceived) returns to education and the demand for schooling. Q J Econ 125:515–548
Kahneman D, Tversky A (1979) Prospect theory: An analysis of decision under risk. Econom J Econom Soc 263–291
Kelley HH, Holmes JG, Kerr NL, et al (2003) An atlas of interpersonal situations. Cambridge University Press
Kelsey D, le Roux S (2018) Strategic ambiguity and decision-making: an experimental study. Theory Decis 84:387–404. https://doi.org/10.1007/s11238-017-9618-8
Kimmich C (2012) Networks of Coordination and Conflict: Governing electricity transactions for irrigation in South India. Dissertation, Humboldt-Universität zu Berlin

Kimmich C (2013a) Linking action situations: Coordination, conflicts, and evolution in electricity provision for irrigation in Andhra Pradesh, India. Ecol Econ 90:150–158. https://doi.org/10.1016/j.ecolecon.2013.03.017

Kimmich C (2016) Can Analytic Narrative Inform Policy Change? The Political Economy of the Indian Electricity–Irrigation Nexus. J Dev Stud 52:269–285. https://doi.org/10.1080/00220388.2015.1093119

Kimmich C (2013b) Incentives for energy-efficient irrigation: Empirical evidence of technology adoption in Andhra Pradesh, India. Energy Sustain Dev 17:261–269. http://dx.doi.org/10.1016/j.esd.2013.02.004

Kimmich C (2013c) Networks of Coordination and Conflict: Governing electricity transactions for irrigation in South India. Shaker, Aachen

Kimmich C, Baldwin E, Kellner E, et al (2022) Networks of action situations: a systematic review of empirical research. Sustain Sci. https://doi.org/10.1007/s11625-022-01121-2

Kimmich C, Fischbacher U (2016) Behavioral determinants of supply chain integration and coexistence. J For Econ 25:55–77. https://doi.org/10.1016/j.jfe.2016.08.001

Kimmich C, Gallagher L, Kopainsky B, et al (2019) Participatory modeling updates expectations for individuals and groups, catalyzing behavior change and collective action in water-energy-food nexus governance. Earths Future 7:1337–1352. https://doi.org/10.1029/2019EF001311

Kimmich C, Sagebiel J (2016) Empowering irrigation: A game-theoretic approach to electricity utilization in Indian agriculture. Util Policy 43, B:174–185. https://doi.org/10.1016/j.jup.2016.10.002

Kimmich C, Villamayor-Tomás S (2019) Assessing Action Situation Networks: A Configurational Perspective on Water and Energy Governance in Irrigation Systems. Water Econ Policy 1850005. https://doi.org/10.1142/S2382624X18500054

Kimmich C, Weyerstraß K, Czypionka T, et al (2025) Economic impact of labor productivity losses induced by heat stress: an agent-based macroeconomic approach. Clim Change 178:36. https://doi.org/10.1007/s10584-025-03879-7

Klein B, Crawford RG, Alchian AA (1978) Vertical Integration, Appropriable Rents, and the Competitive Contracting Process. J Law Econ 21:297–326

Kliemt H (2011) Tayloring Game Theory the Ostrom Way. Good Soc 20:37–49. https://doi.org/10.5325/goodsociety.20.1.0037

Kocher MG, Lahno AM, Trautmann ST (2018) Ambiguity aversion is not universal. Eur Econ Rev 101:268–283. https://doi.org/10.1016/j.euroecorev.2017.09.016

Krugman P (1991) History versus Expectations. Q J Econ 106:651–667. https://doi.org/10.2307/2937950

Künneke R, Groenewegen J, Ménard C (2010) Aligning modes of organization with technology: Critical transactions in the reform of infrastructures. J Econ Behav Organ 75:494–505

Kydd J, Dorward A (2004) Implications of market and coordination failures for rural development in least developed countries. J Int Dev 16:951–970. https://doi.org/10.1002/jid.1157

Long NE (1958) The Local Community as an Ecology of Games. Am J Sociol 64:251–261

Lubell M (2013) Governing Institutional Complexity: The Ecology of Games Framework. Policy Stud J 41:537–559. https://doi.org/10.1111/psj.12028

Lubell M, Morrison TH (2021) Institutional navigation for polycentric sustainability governance. Nat Sustain 4:664–671. https://doi.org/10.1038/s41893-021-00707-5

Mahoney J (2004) Economic Foundations of Strategy. SAGE Publications, Inc., Thousand

Oaks, California
Manski CF (2004) Measuring Expectations. Econometrica 72:1329–1376. https://doi.org/10.1111/j.1468-0262.2004.00537.x
Manski CF (2018) Survey Measurement of Probabilistic Macroeconomic Expectations: Progress and Promise. NBER Macroecon Annu 32:411–471. https://doi.org/10.1086/696061
March JG (1978) Bounded Rationality, Ambiguity, and the Engineering of Choice. Bell J Econ 9:587–608
Matzner E, Bhaduri A (1998) The Socioeconomic Context: An Alternative Approach to Popper's Situational Analysis. Philos Soc Sci 28:484–497. https://doi.org/10.1177/004839319802800402
McAdams RH (2009) Beyond the prisoner's dilemma: coordination, game theory, and law. 82 South Calif Law Rev 209:231–233
McGinnis MD (2011) Networks of Adjacent Action Situations in Polycentric Governance. Policy Stud J 39:51–78. https://doi.org/10.1111/j.1541-0072.2010.00396.x
McGinnis MD (1986) Issue linkage and the evolution of international cooperation. J Confl Resolut 30:141–170
McKelvey RD, Niemi RG (1978) A multistage game representation of sophisticated voting for binary procedures. J Econ Theory 18:1–22. https://doi.org/10.1016/0022-0531(78)90039-X
McKenzie D, Gibson J, Stillman S (2013) A land of milk and honey with streets paved with gold: Do emigrants have over-optimistic expectations about incomes abroad? Migr Dev 102:116–127. https://doi.org/10.1016/j.jdeveco.2012.01.001
Medina Sierra LF (2007) A unified theory of collective action and social change. University of Michigan Press, Ann Arbor
Ménard C (2004) The Economics of Hybrid Organizations. J Insitutional Theor Econ 160:345–376
Mewhirter J, Lubell M, Berardo R (2018) Institutional externalities and actor performance in polycentric governance systems. Environ Policy Gov 28:295–307. https://doi.org/10.1002/eet.1816
Millner A, Dietz S, Heal G (2013) Scientific Ambiguity and Climate Policy. Environ Resour Econ 55:21–46. https://doi.org/10.1007/s10640-012-9612-0
Montes N, Osman N, Sierra C (2022) A computational model of Ostrom's Institutional Analysis and Development framework. Artif Intell 311:103756. https://doi.org/10.1016/j.artint.2022.103756
Morgan MG, Keith DW (2008) Improving the way we think about projecting future energy use and emissions of carbon dioxide. Clim Change 90:189–215. https://doi.org/10.1007/s10584-008-9458-1
Moscati I (2019) Measuring utility: From the marginal revolution to behavioral economics. Oxford University Press
Müller B, Balbi S, Buchmann CM, et al (2014) Standardised and transparent model descriptions for agent-based models: Current status and prospects. Environ Model Softw 55:156–163. https://doi.org/10.1016/j.envsoft.2014.01.029
Müller M, Rommel J, Kimmich C (2018) Farmers' adoption of irrigation technologies: Experimental evidence from a coordination game with positive network externalities in India. Ger Econ Rev 19:119–139
Nockur L, Arndt L, Keller J, Pfattheicher S (2020) Collective choice fosters sustainable resource management in the presence of asymmetric opportunities. Sci Rep 10:10724. https://doi.org/10.1038/s41598-020-67757-1
Oakley A (1999) Economics and the origin of Popper's situational analysis. Hist Econ Rev

30:25–40. https://doi.org/10.1080/10370196.1999.11733310
Oberlack C, Sietz D, Bonanomi EB, et al (2019) Archetype analysis in sustainability research. Ecol Soc 24:. https://doi.org/10.2307/26796959
Ostrom E (1990) Governing the commons: the evolution of institutions for collective action. Cambridge University Press, Cambridge, New York
Ostrom E (2010a) Beyond Markets and States: Polycentric Governance of Complex Economic Systems. Am Econ Rev 100:641–672. https://doi.org/doi: 10.1257/aer.100.3.641
Ostrom E (2010b) Polycentric systems for coping with collective action and global environmental change. Glob Environ Change 20:550–557
Ostrom E (2005) Understanding institutional diversity. Princeton University Press, Princeton, Oxford
Ostrom E, Gardner R, Walker J (1994) Rules, Games and Common-Pool Resources. The University of Michigan Press, Michigan
Ostrom E, Parks RB, Whitaker GP (1973) Do We Really Want to Consolidate Urban Police Forces? A Reappraisal of Some Old Assertions. Public Adm Rev 33:423–432. https://doi.org/10.2307/974306
Ostrom V, Tiebout CM, Warren R (1961) The Organization of Government in Metropolitan Areas: A Theoretical Inquiry. Am Polit Sci Rev 55:831–842
Pittel K, Rübbelke DirkTG (2012) Transitions in the negotiations on climate change: from prisoner's dilemma to chicken and beyond. Int Environ Agreem Polit Law Econ 12:23–39. https://doi.org/10.1007/s10784-010-9126-6
Plott CR, Smith VL (2008) Handbook of experimental economics results, 1st ed. North Holland, Amsterdam
Poteete AR, Janssen M, Ostrom E (2010) Working together: collective action, the commons, and multiple methods in practice. Princeton University Press, Princeton, NJ
Putnam RD (1988) Diplomacy and domestic politics: the logic of two-level games. Int Organ 42:427–460
Ragin CC (2014) The comparative method: Moving beyond qualitative and quantitative strategies. Univ of California Press
Rapoport A (1967) Exploiter, leader, hero, and martyr: The four archetypes of the 2 × 2 game. Behav Sci 12:81–84. https://doi.org/10.1002/bs.3830120202
Robinson D, Goforth D (2005) The topology of the 2x2 games: a new periodic table. Routledge, London; New York
Rodrik D (2014) When ideas trump interests: Preferences, worldviews, and policy innovations. J Econ Perspect 28:189–208
Runge CF (1981) Common Property Externalities: Isolation, Assurance, and Resource Depletion in a Traditional Grazing Context. Am J Agric Econ 63:595–606
Runge CF (1986) Common property and collective action in economic development. World Dev 14:623–635
Scharpf FW (1990) Games Real Actors Could Play. Ration Soc 2:471–494. https://doi.org/10.1177/10434631900020040
Scharpf FW (1997) Games real actors play: actor-centered institutionalism in policy research. Westview Press, Boulder, Colo.
Schelling TC (1978) Micromotives and macrobehavior, 1st edn. Norton, New York
Schlager E, Villamayor-Tomas S (2023) The IAD framework and its tools for policy and institutional analysis. In: Weible CM (ed) Theories of the policy process. Routledge, pp 196–229
Schneider V (2025) Germany's Energy and Climate Policy as an Ecology of Games. Polit Gov 13:
Schwalm CR, Glendon S, Duffy PB (2020) Reply to Hausfather and Peters: RCP8. 5 is neither

problematic nor misleading. Proc Natl Acad Sci 117:27793–27794
Sen AK (1967) Isolation, Assurance and the Social Rate of Discount. Q J Econ 81:112–124
Sendzimir J, Flachner Z, Pahl-Wostl C, Knieper C (2010) Stalled regime transition in the upper Tisza River Basin: the dynamics of linked action situations. Environ Sci Policy 13:604–619. http://dx.doi.org/10.1016/j.envsci.2010.09.005
Skyrms B (2004) The stag hunt and the evolution of social structure. Cambridge University Press, Cambridge, UK ; New York
Smajgl A, Izquierdo LR, Huigen M (2008) Modeling endogenous rule changes in an institutional context: The ADICO sequence. Adv Complex Syst 11:199–215. https://doi.org/10.1142/S021952590800157X
Smaldino PE, Lubell M (2011) An Institutional Mechanism for Assortment in an Ecology of Games. PLOS ONE 6:e23019. https://doi.org/10.1371/journal.pone.0023019
Snidal D (1985) Coordination versus Prisoners' Dilemma: Implications for International Cooperation and Regimes. Am Polit Sci Rev 79:923–942. https://doi.org/10.2307/1956241
Swart RJ, Raskin P, Robinson J (2004) The problem of the future: sustainability science and scenario analysis. Glob Environ Change 14:137–146. https://doi.org/10.1016/j.gloenvcha.2003.10.002
Tan R, Xiong C, Kimmich C (2023) An agent-situation-based model for networked action situations: Cap-and-trade land policies in China. Land Use Policy 131:106743. https://doi.org/10.1016/j.landusepol.2023.106743
Tesfatsion L, Judd KL (2006) Handbook of Computational Economics. Elsevier, Amsterdam
Tetlock PE, Mellers BA, Scoblic JP (2017) Bringing probability judgments into policy debates via forecasting tournaments. Science 355:481. https://doi.org/10.1126/science.aal3147
Tsebelis G (1988) Nested games: the cohesion of french electoral coalitions. Br J Polit Sci 18:145–170
Villamayor-Tomas S, Grundmann P, Epstein G, et al (2015) The water-energy-food security nexus through the lenses of the value chain and the Institutional Analysis and Development frameworks. Water Altern 8:735–755
Voinov A, Kolagani N, McCall MK, et al (2016) Modelling with stakeholders – Next generation. Environ Model Softw 77:196–220. https://doi.org/10.1016/j.envsoft.2015.11.016
Wellman MP, Tuyls K, Greenwald A (2025) Empirical Game Theoretic Analysis: A Survey. J Artif Intell Res 82:1017–1076
Williamson OE (1979) Transaction-cost economics: the governance of contractual relations. J Law Econ 233–261

Appendix: Articles

	Title	doi
1	Behavioral determinants of supply chain integration and coexistence	10.1016/j.jfe.2016.08.001
2	Empowering irrigation: A game-theoretic approach to electricity utilization in Indian agriculture	10.1016/j.jup.2016.10.002
3	Participatory modelling updates expectations for individuals and groups, catalyzing behavior change and collective action in nexus governance	10.1029/2019EF001311
4	Visions before models: The ethos of energy modeling in an era of transition	10.1016/j.erss.2022.102497
5	Assessing action situation networks: a configurational perspective on water and energy governance in irrigation systems	10.1142/S2382624X18500054
6	Archetypal games generate diverse models of power, conflict, and cooperation	10.5751/ES-12668-260402
7	Networks of action situations: a systematic review of empirical research	10.1007/s11625-022-01121-2