Global socio-technical regimes

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Abstract

This paper addresses the question why socio-technical transitions follow similar trajectories in various parts of the world, even though the relevant material preconditions and institutional contexts vary greatly between different regions and countries. It takes a critical stance on the implicit methodological nationalism in transition studies' socio-technical regime concept and proposes an alternative 'global' regime perspective that embraces the increasingly multi-scalar actor networks and institutional rationalities, which influence transition dynamics beyond national or regional borders. By drawing on globalization theories from sociology and human geography, we show that socio-technical systems often develop institutional rationalities that are diffused via international networks and thus become influential in various places around the world. In so doing, we shed light on the multi-scalar interrelatedness of institutional structures and actors in socio-technical systems and elaborate on the implications for the conceptualization of transition dynamics. The paper illustrates this with the case study of an unsuccessful transition in the Chinese wastewater sector. Recent studies indicate that key decisions on wastewater infrastructure expansion were not only influenced by path-dependencies stemming from China's national context, but equally (or even more critically) by the dominant rationality of the water sector's global socio-technical regime. We conclude by discussing the contours of a new research agenda around the notion of global socio-technical regimes.

1 Introduction

Studies in the field of sustainability transitions aim to explain how socio-technical change unfolds and how a transition towards more sustainable production and consumption processes can be achieved (Markard et al., 2012; van den Bergh et al., 2011). An important assumption is that socio-technical systems are rigid and inert, making change and innovation incremental and path-dependent (Geels, 2002; Markard and Truffer, 2008). Stability in socio-technical systems is attributed to the presence of highly institutionalized formal and informal rules that have co-evolved with certain technologies and solidified into practices and routines. The concept of the *socio-technical regime* has been developed to capture and analyze the substance and effect of these rules of the game on transition dynamics (Karltorp and Sandén, 2012; Kemp et al., 1998; Markard and Truffer, 2008; Smith et al., 2010). The regime denotes the 'deep-structure' or 'grammar' of a socio-technical system, defining appropriate, legitimate and conceivable means-end rationalities in a given sector (Geels, 2010). Transitions are defined as a shift from one socio-technical regime to another, which, according to the multi-level perspective (MLP), happen through a combination of (macro) landscape pressures and (micro) niche developments (Geels and Schot, 2007).

In recent years, theory development in transition studies has shown to incorporate two major trends. First, scholars called for a better conceptualization of regimes, thereby mainly advocating a more sophisticated analysis of institutional structures and processes of institutional change in socio-technical systems (Fuenfschilling and Truffer, 2014; Geels, 2004; Smink et al., 2015; Wirth et al., 2013). It is argued that a regime represents the dominant institutional rationality of a system and that transitions can therefore be described as processes of (de-)institutionalization, i.e. institutional change. To better address the question of how institutional change unfolds, institutional theories from sociology, organizational studies and political science have been used to enrich transition studies. Advancements have been made regarding our understanding of the structuration of regimes (Fuenfschilling and Truffer, 2014; Geels, 2004), the role of actors in changing or maintaining regime rationalities (Fuenfschilling and Truffer, 2016; Jolly et al., 2016; Smink et al., 2015) or the gradual transformation of regimes (Dolata, 2011).

Second, many recent contributions emphasize the need for a more nuanced analysis of the spatial dimensions of transition dynamics (Binz and Truffer, 2017; Coenen et al., 2012; Murphy, 2015; Raven et al., 2012). It is argued that transitions unfold unevenly across space and that certain countries and regions are more apt to transforming their economy than others. Research in the emerging field of 'geography of transitions' has focused on understanding why transitions succeed in some places while they fail in others (Hansen and Coenen, 2015; Raven et al., 2012; Truffer et al., 2015). Using insights from economic and human geography, scholars

have in particular pointed to the importance of specific places, such as cities or regions, as the primary locus of socio-technical change and innovation (Hodson and Marvin, 2010; Murphy, 2015; Späth and Rohracher, 2010). Moreover, they have debunked the idea that niches are local, geographically confined spaces by showing that niches often consist of multi-scalar actor networks and discourses that get implemented in many places at once (Binz et al., 2016b; Fontes et al., 2016; Raven et al., 2012; Sengers and Raven, 2015; Wieczorek et al., 2015).

While institutionalists tend to ask the question why things are so similar (pointing to the structuration of regimes), geographers rather ask why things are so different (pointing to the diversity of niche developments in different places), which, according to us, is one of the main reasons why the two research streams do not show much overlap at this point. As a consequence, there is a substantial lack of understanding regarding the spatial specificities of socio-technical regimes. In this paper, we want to make a first step towards fruitfully combining the two perspectives. We argue that in order to understand transition dynamics it is crucial to not only study the multi-scalar characteristics of particular niches (as geographers have done), but also the spatial particularities of regimes, i.e. of dominant institutional rationalities (which are the domain of institutional scholars).

In order to develop a more spatially sensitive regime concept, we will draw on theoretical approaches from sociology and human geography that have explicitly dealt with questions of space in the construction and diffusion of institutional and social structures. Empirical evidence suggests that institutional structures, such as cultural-cognitive rationalities, norms and regulations, as well as the actor networks that are crucial in constructing and diffusing them, are today increasingly internationalized. Contributions in the realm of neo-institutional theory have traced the existence of a universally valid institutional rationality since World War II that shapes the development of many industries worldwide (Boli and Thomas, 1997; Meyer, 1996; Meyer et al., 1997; Meyer et al., 2009). This literature explains why and how a global culture develops, what it is made of, how it diffuses across national boundaries and to what extent it shapes local contexts (and vice versa). On the other hand, literature on global production networks (GPN) and global value chains (GVC) has argued that in today's globalizing knowledge economy, many sectors evolve in internationalized actor networks which regulate production and innovation processes in a geographically fragmented manner, beyond the confines of regionally or nationally defined territorial boundaries (Gereffi et al., 2005; Henderson et al., 2002; Yeung and Coe, 2015).

It is therefore increasingly plausible to assume that socio-technical regimes achieve validity beyond the immediate national contexts. This paper therefore proposes an internationalized conceptualization of socio-technical regimes and elaborates on the implications thereof for the study of sustainability transitions.

The paper continues as follows. Chapter two will give an overview of the state of the art literature on socio-technical regimes and then introduce the main arguments from globalization theories in sociology and human geography. Chapter three will subsequently outline their implications for a conceptualization of global socio-technical regimes. In chapter four we demonstrate the explanatory value of such an approach with the illustrative case study of how China failed to transition to a potentially more sustainable configuration in its wastewater sector due to various pressures stemming from a global water regime. The paper concludes by outlining an agenda for the study of sustainability transitions, in particular regarding the conceptualization of change, agency and power, as well as space.

2 State of the art on regimes, institutions and globalization

2.1 The evolution of the regime concept

One of the most fundamental claims in transition studies is that socio-technical systems are rigid and inert. Innovation is usually following an incremental trajectory, which makes radical change unlikely. This path-dependency is ascribed to the existence of socio-technical regimes. A well-known basic definition characterized regimes as "*the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures*" (Rip and Kemp, 1998: 340). Regimes were later conceptualized as semi-coherent rule sets carried by different social groups, which stabilize a technological trajectory and function as a selection and retention mechanism (Geels, 2002: 1260; Smith et al., 2005).

The evolution of the regime concept in innovation and transition studies can be described as moving from a conceptualization based on insights of evolutionary economics towards one drawing more on institutional theory (Fuenfschilling and Truffer, 2014; Geels, 2004; Rip and Kemp, 1998; Smith et al., 2005; Van der Vleuten and Högselius, 2012). At the beginning, concepts such as technological paradigms and trajectories, organizational routines or path-dependency took center stage to explain why technological innovation develops incrementally along a specific path (Dosi, 1982; Kemp, 1994; Nelson and Winter, 1982; Rip and Kemp, 1998). Persistence was seen to stem from cognitive models, mostly referring to engineering knowledge and corresponding routinized practices. These notions have later been complemented with a more fine-grained analysis of social structures as regulative, normative and cognitive institutions (Geels, 2004; Van der Vleuten and Högselius, 2012).

While some scholars have defined regimes as to entail material structures (Hoogma et al., 2002; Rip and Kemp, 1998), others have conceptualized them entirely in institutional

terms, stressing first and foremost the “rules of the game”-properties of regimes (Fuenfschilling and Truffer, 2014; Geels, 2004). This paper also follows such a rule-based definition. This does however not imply that materiality is not relevant. On the contrary, materiality, particularly in the form of technologies, is seen to co-evolve with social structures and shape them. The dominant rules of the game that evolve out of such an interaction are, however, institutional and especially cultural-cognitive in nature. The socio-technical regime therefore does not denote concrete social and material practices, but rather the principles that pattern those practices, i.e. the dominant rationality in a system that specifies ideas about cause and effect, defines legitimate means-end-relationships, influences what is conceivable and orders interactions of all sorts (Sewell, 1992). A socio-technical regime can thus be conceptualized as the dominant institutional logic of a socio-technical system (Fuenfschilling and Truffer, 2014; Thornton et al., 2012).

In this conceptualization, regime rationalities are by no means stable and monolithic, but subject to contestation and power battles by interested actors and therefore continuously socially constructed (Fuenfschilling and Truffer, 2016; Geels, 2014; Kern, 2009; Smink et al., 2015). The socio-technical regime can be interpreted as the result of an interplay between actors, technologies and institutions in a system. Rationalities are institutionalized and anchored in various places by codifying them into routines, standards, practices, technologies and so forth. The degree of institutionalization of a regime, and with that its impact on actors, is thus heavily dependent on its translation into practice (Fuenfschilling and Truffer, 2016; Hajer, 1995; Murphy, 2015; Strang and Meyer, 1993).

In terms of explaining innovation and transition dynamics, it has proven fruitful to draw the boundaries of socio-technical regimes at the sectoral level, focusing on socio-technical configurations that ‘fulfill a specific function’, such as water supply and sanitation, energy provision or the organization of transport (Boschma et al., 2017; Geels, 2011; Malerba, 2002). The regime thus develops and manifests itself at the level of the socio-technical system of a given sector.

Despite this spatially open definition of the regime concept in the MLP (Geels, 2002), empirical studies have had a tendency to analyze socio-technical regimes at a national level. This holds true for the historical case studies by Frank Geels, e.g. in case of the transition from horse-drawn carriages to automobiles in American urban passenger transport (Geels, 2005) or the transition from sailing ships to steam ships with a focus on the British regime (Geels, 2002). But also more recent studies of regime dynamics often have an explicit national focus, for instance on the Dutch electricity regime (Raven, 2006; Verbong et al., 2013), the German energy regime (Berlo et al., 2017; Geels et al., 2016; Laes et al., 2014; Strunz, 2014), the ‘water sector in Australia’ (Brown et al., 2013; Dobbie et al., 2014; Fuenfschilling and Truffer, 2016) or on a comparison between national regimes in the same sectors, e.g. wind energy (Lewis,

2011) or solar power (Quitzow, 2015). Notable exceptions include the study of the computational regime by van den Ende and Kemp (1999) as well as the recent call from van der Vleuten and Högselius (2012) to take on a transnational analysis of regimes.

Given this implicit methodological nationalism in transition studies, we currently know very little about how, where and by whom dominant regime rationalities are developed and where exactly they exert influence (or not). Insights form sociology and human geography suggest that cultural-cognitive rationalities can be institutionalized to such a degree that they become taken for granted beyond their place of origin (Bunnell and Coe, 2001; Meyer et al., 1997). Yet, to date, transition literature offers little conceptual insights into the mechanisms and processes that diffuse a cultural-cognitive rationality in space. In the following chapter, we will elaborate on how and why institutional rationalities emerge and gain influence beyond their place of origin and to what extent increasingly internationalized sectoral actor structures abet this development.

2.2 Globalization of institutional structures: The emergence of a world polity

New institutionalism has become one of the most influential theories in sociology, specifically in the realm of organization studies. Over the years, it has developed into the leading theory of organizational development and change (Greenwood et al., 2008; Powell and DiMaggio, 1991). As opposed to other approaches, it is mostly concerned with institutional homogenization, i.e. trying to explain why the world looks so similar despite so many different preconditions. The Stanford School around John Meyer has put forward the idea of an inherently Western, but globally valid world polity, which *"is constituted by distinct culture - a set of fundamental principles and models, mainly ontological and cognitive in character, defining the nature and purposes of social actors and action"* (Boli and Thomas, 1997; Meyer et al., 1997).

This culture entails a set of rules, also called scripts, models or frames, which not only define specific purposes (e.g. progress and development) or principles and values (justice, equality, human rights), but also constitute legitimate actor categories such as nation-states, organizations or individuals. The content of such a universally valid rationality is constantly socially constructed by specific types of actors. Nation-states, multinational corporations (MNCs) and intergovernmental organizations (IGOs) assumedly enjoy authority in terms of military, economic and political power (Boli and Thomas, 1997). Of specific importance in the construction of world culture are furthermore voluntary associations like international non-governmental organizations (INGOs) or social movements that enact, propagate and organize a range of different world-cultural issues, as for instance the International Organization for Standardization (ISO), Greenpeace or the World Wild Fund for Nature (WWF) (ibid.). In

addition, professions and scientists are considered legitimate experts that exert a crucial definitional authority over cause-effect and mean-end relationships and in so doing heavily shape institutional structures within a certain field (Abbott, 1988; DiMaggio, 1991; Hwang and Powell, 2009; Scott, 2008; Suddaby and Viale, 2011).

The most striking effect of the existence of such a world polity is isomorphism (DiMaggio and Powell, 1983; Meyer and Rowan, 1977). In many organizational fields, actors and practices have become increasingly similar all over the world, which is believed to be a consequence of the enactment of world polity scripts (Meyer et al., 1997). No matter the local particularities, actors are forced to conform to certain models if they want to gain legitimacy and signal that they are modern, rational, and progress-oriented. The institutionalization of those models then leads to structural similarity between actors and practices. One example is the nation-states themselves, who tend to adopt very similar policies, e.g. in terms of gender equality, environmental sustainability or public education regardless of their national cultural history. A case in point is the rise of women in higher education. One might assume that female enrollments in universities would increase in developed more than in developing economies or in predominantly Christian more than in Islamic countries. However, Meyer et al. show that they have increased everywhere at about the same time, which *"makes sense only if common world forces are at work"* (Meyer et al., 1997, p. 152):

> *"A considerable body of evidence supports our proposition that world society models shape nation-state identities, structures, and behavior via worldwide cultural and associational processes. Carried by rationalized others whose scientific and professional authority often exceeds their power and resources, world culture celebrates, expands, and standardizes strong but culturally somewhat tamed national actors. The result is nation-states that are more isomorphic than most theories would predict and change more uniformly than is commonly recognized. As creatures of exogenous world culture, states are ritualized actors marked by extensive internal decoupling and a good deal more structuration than would occur if they were responsive only to local cultural, functional, or power processes."* (Meyer et al., 1997, p. 173)

Isomorphism is imposed through institutional pressures present in an organizational field (Beckert, 2010b; DiMaggio and Powell, 1983; Mizruchi and Fein, 1999). Neo-institutional theory usually refers to pressures stemming from regulative, normative or cultural-cognitive institutions (Scott, 1995). While regulations exert coercive pressures within a field, normative institutions, such as labels or professional codes, mainly work through pressures to standardize social behavior. In addition, cultural-cognitive institutions, such as rationalities and beliefs, exert mimetic pressures at a pre-conscious level within organizational fields. Actors are believed to copy institutional templates that are perceived as highly legitimate in a field, particularly in situations characterized by high uncertainty and complexity. Since actors within

a field operate in the same institutional environment, the prevailing institutional pressures of coercion, standardization and mimesis make them structurally similar over time.

This isomorphism argument has, albeit supported by a range of empirical studies, also brought about criticism. Institutional scholars in various disciplines have taken on a comparative perspective instead, assuming a great deal of variety and divergence (Beckert, 2010b; Eisenstadt and Schluchter, 1998). These include, for instance, the 'varieties of capitalism' approach (Hall and Soskice, 2001; Hall and Thelen, 2009), historical institutionalism (Dobbin, 1994; Streeck and Thelen, 2005) or economic sociology (Guillén, 2001). Besides accounting for the obviously still existing regional institutional variations, a central scholarly concern is the conceptualization of field-level change: Where do sources of change lie and how can change unfold if the world polity is all-encompassing? The answer of world polity scholars is usually to refer to the inherent contradiction of the world polity itself, whose semi-coherence will always lead to contestation and thus leave enough room for change (Meyer, 1999). In addition, some scholars have engaged in research on *glocalization*, identifying the tensions between a global culture and local specificities as a driving force for innovation and change and promoting the idea that the global and the local are mutually constitutive (Courchene, 1995; Drori et al., 2014; Ritzer, 2003; Robertson, 1995).

In this paper we argue that this is where the sociological study of isomorphism can greatly benefit from the geographical study of heterogeneity. Literature on global production networks (GPN) and global value chains (GVC) has convincingly pointed to the fact that economic structures connect some places to each other while leaving out others (Dicken, 2015; Yeung and Coe, 2015). Therefore, rather than universally binding rationalities, they find evidence of a variety of similar rationalities in different places around the world. This nuance is important, since it allows us to hypothesize where and how rationalities emerge and diffuse and what kind of innovation might be generated in the process. The next section will review this literature in more detail.

2.3 Globalization of social structures: Global production networks and value chains

Global production network (GPN) and value chain (GVC) literature argues that through the disaggregation and dispersion of economic activities to multiple geographic locations, manufacturing and service sectors are increasingly organized at an international scale (Coe et al., 2004; Dicken, 2015; Gereffi, 1999; Levy, 2008). Global value chains are defined as "*sets of interorganizational networks clustered around one commodity or product, linking households, enterprises, and states to one another within the world-economy*" (Gereffi and Korzeniewicz, 1994: 2). These sector-specific networks have become the backbone of the global economy as more than 80% of global trade is taking place in the complex networks spanning

lead firms and their global suppliers (Yeung and Coe, 2015). Global value chains are at the same time locally integrated, internationally dispersed and socially constructed, underscoring the social embeddedness of economic organization (Gereffi and Korzeniewicz 1994). In the GVC perspective, multinational companies (MNCs) with their outstanding organizational capacity and geographic reach play a key role in integrating the production, distribution and consumption patterns in various places around the world (Gereffi, 1999).

GPN literature goes a step further in using a broad network metaphor for analyzing the '*nexus of interconnected functions and operations through which goods and services are produced, distributed and consumed*' worldwide (Henderson et al., 2002: 445). Extensive empirical analysis of the GVC and GPN of e.g. car manufacturing, apparel, or consumer electronics showed that lead firms (MNCs from industrialized economies), their specialized suppliers (typically original equipment manufacturers (OEM) in emerging economies) and various intermediary actors interact in complex networks that organize production and value capture while also facilitating the international diffusion of knowledge, investment and technology standards (Coe et al., 2008; Dicken, 2015; Gereffi, 1999; Hess and Yeung, 2006). Who appropriates the value added in production, where and how innovation develops, and who is empowered to exert influence on the development of a sector's GPN is contingent on actors' specific structural positions in these multi-scalar networks. In most production networks, lead firms from developed economies (e.g. Apple, Toyota, Nestle) dominate the network's governance and are thus able to exert most direct agency, while actors with more limited resources and capabilities – like OEM suppliers in developing countries – occupy more peripheral network positions with limited bargaining power (Gereffi et al., 2005; MacKinnon, 2012).

Notions such as 'value chain governance' (Gereffi et al., 2005) were used to analyze the power asymmetries and international coordination and contestation mechanisms in these networks. Depending on a sector's consumption and production patterns, complexities of transactions and the capabilities in the supplier base, the global network configuration is more or less hierarchical, leaving non-lead actors in more or less captive positions (Gereffi et al., 2005). While GVC/GPN literature remained focused on analyzing the organization of production, knowledge diffusion, and the catching-up trajectories of latecomer countries (MacKinnon, 2012; Morrison et al., 2008), we here argue that its conceptual perspective can be useful for theorizing the diffusion of dominant regime rationalities beyond national borders.

In particular in sectors that are structured around highly hierarchical global value chains (like the water sector which is dominated by a relatively small set of multinational companies, development banks and engineering consulting firms), peripheral actors will be forced to not only emulate the lead firm's knowledge base, but also its culture, rule-sets and key organizational routines (Levy, 2008; Yeung, 2009). The more hierarchical the network

structure, the more direct this transfer of dominant regime rationalities will work throughout space. Spatially disparate regions that are involved in the same global production network can thus be expected to experience strong institutional pressures in adapting their structural properties to a given GPN. Mimetic pressures become particularly relevant for peripheral actors that want to gain access to the knowledge, resources and markets in an existing GPN; often they will have to adapt the local institutional structures and governance arrangements to better fit the dominant MNC's strategic needs in a process of 'strategic coupling' (Coe et al., 2004; MacKinnon, 2012).

In addition to MNCs, which are the main carrier of knowledge and influence in GVC literature, international diffusion channels for dominant institutions also include non-firm networks (MacKinnon, 2012; Parrilli et al., 2013; Yeung and Coe, 2015). Empirical studies showed that regulation and control of GPN are increasingly structured around distributed and internationalized expert networks (McCann and Ward, 2010). Key agents with high social legitimacy, such as academic technology experts, 'traveling technocrats', high-to mid-level policy experts, or members of the 'global consultocracy' repeatedly move from one place to the next in a GPN, thereby diffusing a cognitive model of 'successful projects' in space (Larner and Laurie, 2010; Saint-Martin, 2004; Sengers and Raven, 2015). Sengers and Raven (2015) provide an illustrative example of that phenomenon, tracing the global diffusion of bus rapid transfer systems to the strategic agency and spatial mobility of two academia-driven INGOs, various investment and development banks, university experts, as well as the mayors of Bogota and Curitiba acting as high-status technology proponents. As specialized technology and planning expertise got integrated in dense transnational expert networks, visions of a desirable future for one place got increasingly inspired by what had already been done elsewhere, in particular in pioneering cities in South America (Amin, 2002; Sengers and Raven, 2015).

The professional culture of a sector is thus not exclusively constructed in territorially confined clusters anymore, but in spatially dispersed communities that bond their members through e.g. the activities of specialized trade associations, internationally mobile expert communities, INGOs or repeated short-term spatial proximity created at trade fairs, conferences and international workshops (Amin, 2002; Binz and Truffer, 2017; Coe and Bunnell, 2003; Crevoisier and Jeannerat, 2009; Maskell et al., 2006). Yet, despite the mounting evidence from different disciplines that institutional as well as social structures are multi-scalar, no clear concept has been developed for the transnational institutionalization processes through which regime rationalities emerge and shape transition dynamics in various places at once. Chapter three thus represents a first step in the development of such a framework.

3 Towards a global regime concept

As outlined above, socio-technical regimes evolve inside a given sector (Boschma et al., 2017). Transition studies to date mostly looked at radical change in infrastructure sectors, such as housing, energy, transport, water or food (Markard et al., 2012). There is growing evidence that these sectors exhibit an internationalized actor structure similar to the examples from world polity and GPN studies. They are furthermore also subjected to international regulation through supranational treaties, norms or certifications, e.g. regarding intellectual property rights and public procurement (i.e. WTO and GATT), technology and management standardization (i.e. ISO standards), fair trade (i.e. labels by the rainforest alliance), as well as environmental standards (i.e. the Kyoto protocol or the Paris agreement on climate change) (Gosens et al., 2015; Manning and Reinecke, 2016).

When taking a closer look at transition processes in these sectors, it becomes evident that the range of new socio-technical options available does not vary as greatly between countries as one could expect (Markard, 2011). Instead, technology choices revolve around the same regime rationality in highly divergent regions. Examples comprise the global mushrooming of Bus Rapid Transfer Systems (Sengers and Raven, 2015), the implementation of the same 'modern city' architecture principles in cities as diverse as Dubai, Shanghai, Mumbai and St. Petersburg (Brook, 2013) or the case we discuss in more detail later – the diffusion of standard wastewater infrastructure into desert cities in China, Africa or the Arab peninsula (Monstadt and Schramm, 2017; van Welie et al., forthcoming).

A global regime perspective thus starts from the notion that actors in socio-technical systems are heavily engaged in the creation, maintenance and disruption of guiding institutional rationalities, which emerge from and are maintained within hierarchical firm and non-firm networks. A global socio-technical regime can thus be defined as *the dominant institutional rationality in a socio-technical system, which depicts a structural pattern between actors, institutions and technologies that has reached validity beyond specific territorial contexts, and which is diffused through internationalized networks*.

This definition incorporates various fruitful overlaps between world polity and GPN studies. Two points in particular warrant further explanation; first, we conceptualize global regimes not as a monolithic and deterministic phenomenon, but rather as a semi-coherent, multi-scalar institutional rationality that is permanently contested and re-produced. Second, different types of actors will have varying influence on the dominant institutional rationality. An actor's capacity to exert institutional pressures as well as its position in the (often hierarchical) international networks of a sector's GPN will determine their power to change the trajectory of the regime.

3.1 Semi-coherent, multi-scalar institutional rationality

Regimes denote a semi-coherent deep structure that is the result of a long-term alignment and co-evolution of institutions, actors and technologies at different geographical scales. In global regimes, these rules of the game exert validity beyond a specific local context. In many cases, the validity is congruent with the corresponding global production networks and value chains, thus being international, but not necessarily universal, in nature. As Fuenfschilling and Truffer (2014) have shown in their article, the level of institutional pressure emanating from a regime depends on its strength, i.e. on its level of structuration or degree of institutionalization. Drawing on various institutional scholars (Hajer, 1995; Jepperson, 1991; Johnson et al., 2006; Scott, 1987; Zucker, 1977), we assume that structuration increases with scale and scope of diffusion (e.g. implementation across geographical or sectoral domains), duration of existence, starkness (e.g. low controversy), invulnerability to social intervention (e.g. resistance towards innovations or counter movements), internal coherence (e.g. few contradictions) and embeddedness (e.g. good fit with surrounding context). In addition, institutionalization is typically highest when principles have been translated into binding formal or material structures in practice, such as policies, technologies, actors, financial investments or routines.

Figure 1 correspondingly depicts a way of analyzing regimes as a semi-coherent assemblage of competing institutional logics. In many systems, various institutional rationalities will co-exist and influence each other. In the case of the Australian water sector, three competing ideal-type rationalities - a ‘hydraulic’, ‘market’ and ‘water sensitive’ logic - could be identified (cf. section 4.1). The regime then denotes the semi-coherent assemblage of elements of various ideal-type rationalities which are most deeply institutionalized (the core of the circle in darker shade), while elements of other institutional rationalities are much more fluid, unstable and thus less influential.

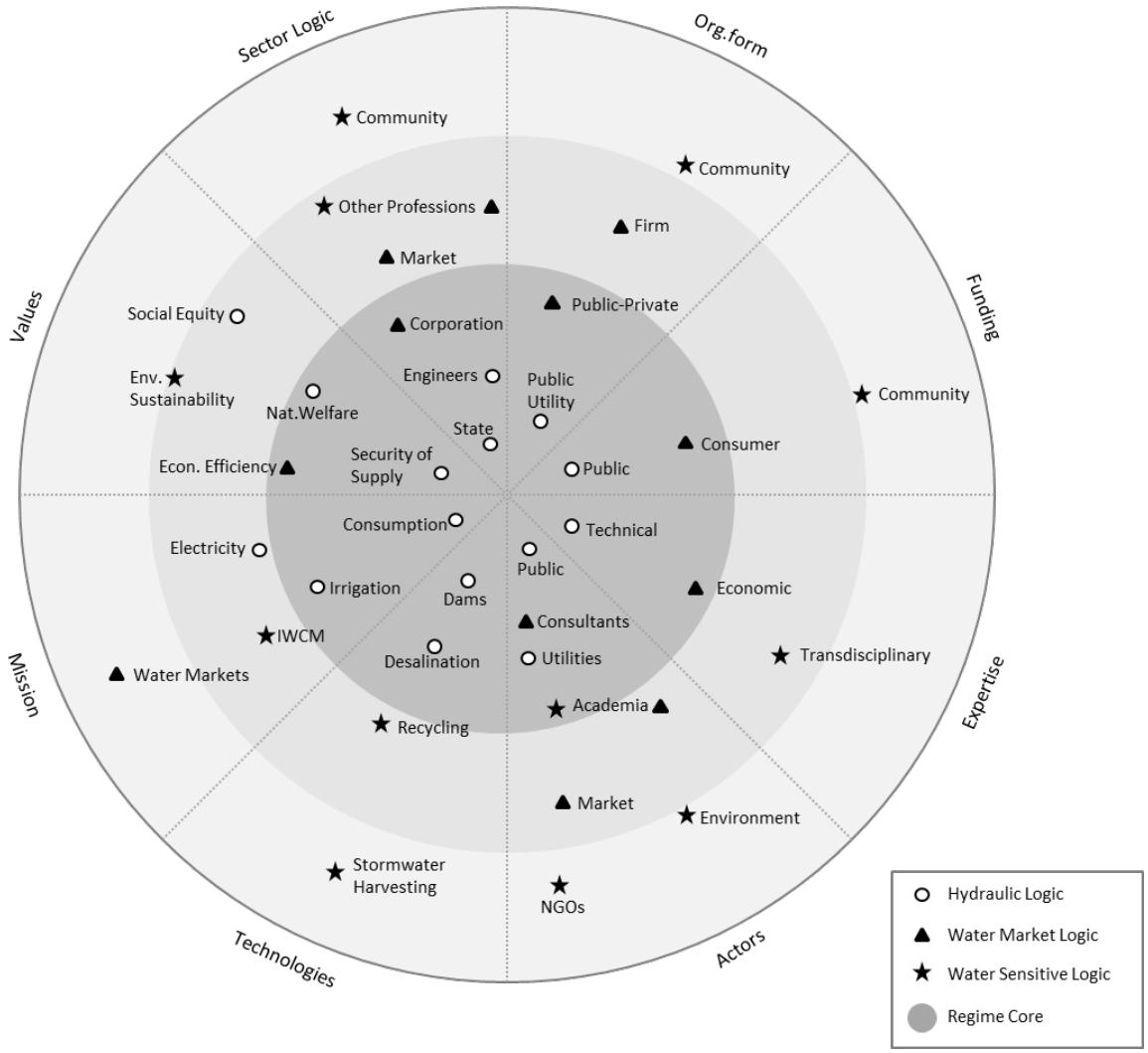

Figure 1: Competing institutional rationalities in the Australian urban water regime as depicted by Fuenfschilling and Truffer (2014).

As cultural-cognitive rationalities, regimes will first and foremost exert mimetic pressures within a socio-technical system. Actors will follow the shared logic of action because it is perceived as 'the normal thing to do'. However, translated into regulative and normative institutions, regime rationalities can also exert coercive and normative pressures within the system. In addition, institutional rationalities also materialize in technologies, which enhances their dominance even further. The more a regime becomes institutionalized, the more it will be perceived as unparalleled. In particular, we argue that the mimetic pressure emanating from a regime increases with the diffusion and implementation of its rationality into different geographical contexts. Global regimes will be strongest in socio-technical systems where a dominant rationality has widely diffused into regions with diverse cultural, institutional and material preconditions and where its scripts have been translated into international standards and norms (cf. Figure 2A). Conversely, if a given sector depends on a variety of competing

rationalities that are institutionalized to varying degrees in different places or co-exist in 'fragmented' or 'splintered' regimes (van Welie et al., forthcoming), the mimetic pressure from a global regime is expected to be lower (cf. Figure 2B).

These multi-scalar processes of institutionalization increase the semi-coherent nature of global regimes and thus contribute to specific transition dynamics. In contrast to world polity literature, we argue that the socio-technical configurations resulting from the translation of a global regime in a particular region will always create spatial variations to some degree since the process of translation is subjected to the interplay of global vs. local rationalities (Monstadt and Schramm, 2017). As we will further discuss in the concluding chapter, this interplay may be one of the main sources for transformative change. Places that remain decoupled from a regime's dominant GPN/GVC structure are accordingly more likely to cultivate more independent socio-technical system configurations, which can refrain from isomorphic pressures to some degree. Yet, we would also expect them to remain peripheral to the transition dynamics in the sector in focus. How dominant a specific global regime is vis-à-vis local socio-technical systems and how these processes of glocalization play out is ultimately an empirical question.

In our sector-based conceptualization of socio-technical transitions, both regimes and niches may depend on equally multi-scalar actor networks. Niche solutions such as bus rapid transfer or on-site sanitation have been shown to develop in strongly internationalized actor structures that challenge dominant global regime rationalities in various places at the same time (Binz et al., 2014; Sengers and Raven, 2015). The key difference to global regimes lies in their degree of institutionalization (and thus their structuring impact) as well as in their actor structure. In the case of global niches, actor networks are often loosely structured and depending on spatially dispersed experimentation (Berkhout et al., 2010) or resource formation in 'global innovation systems' (Binz and Truffer, 2017). In the case of regimes, on the other hand, the underlying actor structure resembles a mature GPN with clearly identifiable and resourceful lead actors that coordinate activities around the globe. In terms of their degree of institutionalization, global regimes are assumed to exhibit rationalities stemming from socio-technical configurations that have historically evolved and aligned and have diffused to various places where they significantly impact actors' cognition and behavior or the diffusion of practices. Global niches, on the other hand, often represent rather loosely coupled socio-technical configurations that have not yet developed a coherent rationality or that only play a marginal role in a socio-technical system regarding their scope and scale of diffusion.

Whether or not a sector develops a global regime or whether there exist a variety of local, regional or national regimes and niches is ultimately an empirical question: At what spatial scale does the institutional rationality develop that most critically shapes transition

dynamics in a certain socio-technical system? And how do the relevant scales change over time? The level of analysis that one chooses often influences the degree of homogeneity or variety that will be found. The more a researcher zooms into a certain place or out to the international level, the more likely they are to either find local differences or global trends. However, considering insights of both literature strands discussed above, for most infrastructure sectors today, global regimes will play an important role in explaining transition dynamics.

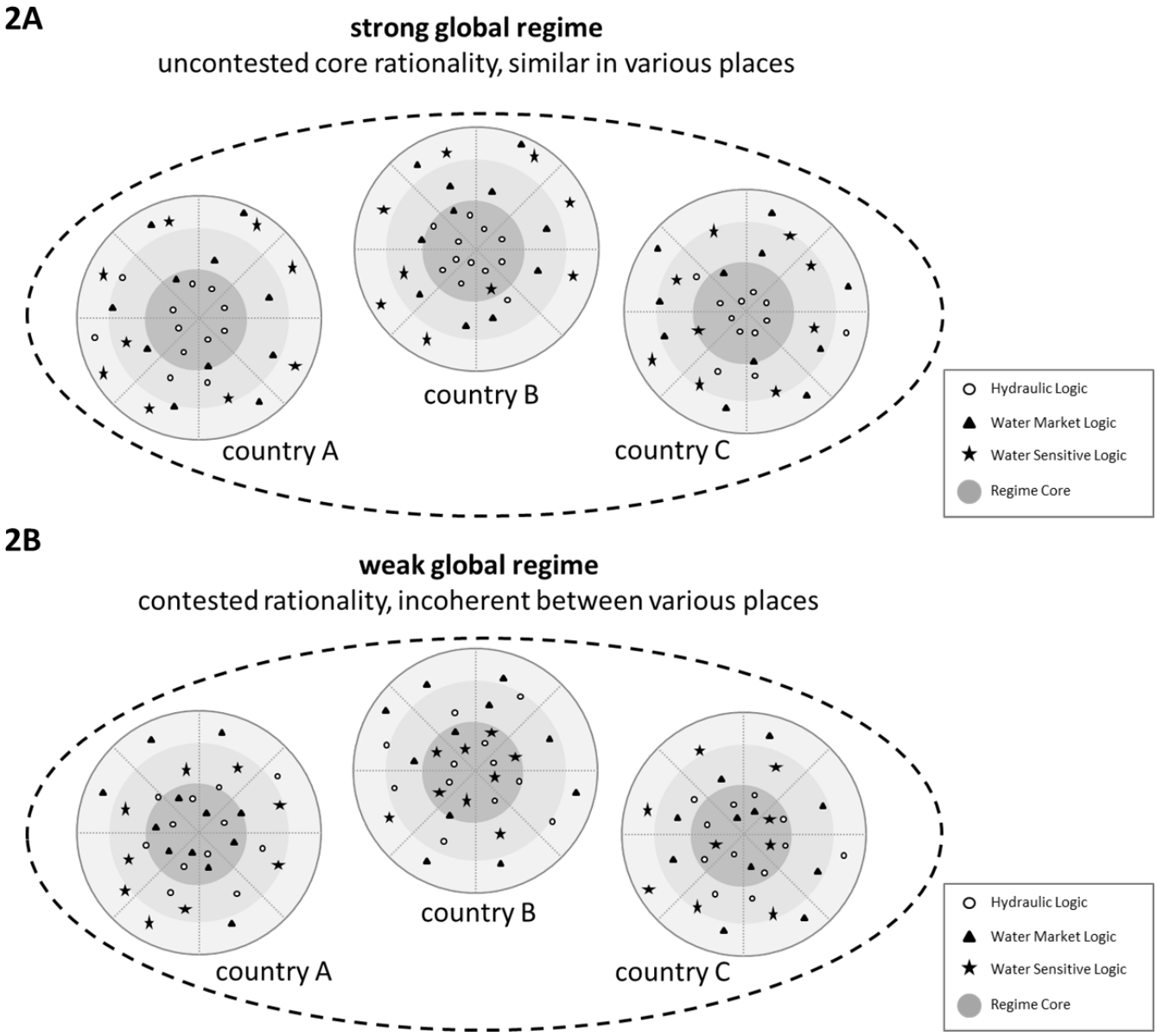

Figure 2: Distinction between strong and weak global regime rationalities

3.2 International social structure with a particular importance of specific actor groups

Given the strong power asymmetries in many sectors' GVCs/GPNs, not all actors are equally important in shaping socio-technical regimes, i.e. their capacity for agency and power

differs (Kern, 2009). Transition studies tend to equate regime actors with powerful incumbent firms or with decision making authorities, often forgetting that these are not necessarily always the most important actors to shape regimes (Fuenfschilling and Truffer, 2016; Geels, 2014; Smink et al., 2015). Taking an institutional as well as network perspective seriously, one should ask: Which actors are most powerful in maintaining or changing institutional rationalities and how does the social structure shape these processes? Put in institutional terms, the question is: Who has enough authority and legitimacy to engage in institutional work? Put in relational terms, one needs to ask: Who is in the best structural (network) position to exert agency?

Regarding the latter, GPN literature suggests that MNCs play a central role in the diffusion of regime rationalities, not just due to their definitional authority, but also due to their superior structural position in global networks. Occupying a central position in global value chains provides them with high connectivity and prestige, which entitles them to a high bargaining power with the opportunity to push for their preferred solutions. Depending on the sector in focus, these networks may be more or less centralized or hierarchical, thus leading to more or less power asymmetry among all involved actors (Gereffi et al., 2005; Yeung, 2009). We expect global regimes that depend on hierarchical GPNs with a few central actors occupying a brokerage position to be stronger than global regimes, which depend on a distributed, scale-free or regular network structure without clear power asymmetries.

Neo-institutional theory adds an important qualification here in arguing that not only MNCs, but also so-called 'generalized others' are crucial in shaping institutional rationalities at an international scale (Meyer and Jepperson, 2000; Suddaby and Viale, 2011). Key actors comprise professions (e.g. scientists, professional associations), INGOs or members of the global 'consultocracy' (e.g. management and engineering consultancies or policy experts). While these actors have limited direct coercive power, they enjoy high definitional authority to direct, narrate and make sense of transformation. Moreover, intermediary actors that have legislative authority or are involved in voluntary standardization processes, such as nation states, IGOs and INGOs are key in constructing, diffusing and institutionalizing certain rationalities in international socio-technical systems (Guler et al., 2002). Finally, they often occupy brokerage positions in the social structure, which allows them steering the information flows between otherwise unconnected network components.

A key question that follows from the above considerations is how (and where) dominant regime rationalities form and how they diffuse in space. Generally, institutional rationalities can develop in a specific local context at first and then diffuse internationally through a gradually internationalizing actor structure. However, given ongoing economic globalization, rationalities are more often than not developing in internationalized networks from the start. In the remainder we will apply our framework to an empirical illustration from the water sector

in order to specify our conceptual claims and identify key research gaps that need to be addressed in this respect.

4 Empirical illustration from the water sector

In the remainder we will first characterize the water sector's global socio-technical regime and then trace the process through which China adopted a large part of this regime rationality between 1990 and 2010. China was chosen as an extreme case to illustrate the considerable mimetic pressures stemming from global regimes. In theory, China is often said to foster a national governance system that is largely independent from outside influences. The national government concentrates considerable political power in a hierarchical administration that is able to defy international standards on e.g. territorial disputes, human rights or economic sanctions imposed by the UN. This observation in principle also applies to China's water sector, which is conditioned by various country-specific context factors that are incompatible with the solutions commonly associated with the global water regime.

First, half of the country's cities (especially in the Northern and North-western regions) are located in semi-arid to arid climate zones and major cities like Beijing or Tianjin belong to the world's driest mega-cities (Jiang, 2009). The current situation in these places is accordingly classified by the UN as an 'acute water crisis' (Jiang, 2009; Yu, 2011). In this context, conventional Western wastewater infrastructure shows considerable functional limitations: In cities that grow faster than 2% p.a., system dimensions are hard to be planned upfront, often causing expensive over- or under-capacities (Maurer, 2009). Also, expansive centralized wastewater systems consume large amounts of freshwater to transport waste to the treatment plant and rely on extended sewer networks which make water recycling prohibitively expensive (Eggimann et al., 2015; National Research Council, 2012).

Second, also at a cultural and political level, China was in a transitory state during most of its wastewater infrastructure transformation. After the political upheaval of the Cultural Revolution, its whole socio-economic system was subject to continued deep structural reforms. While infrastructure sectors in China were traditionally organized as state-owned monopolies under the direct control of government administrations (Voïta, 2009), from the 1990s, various limitations of this governance form became visible. Key problems identified in government reports were 'persistent low investment levels, poor infrastructure quality, and water pollution problems' (Zhong, 2007). Several cities thus started experimenting with novel socio-technical system configurations that included private sector participation and technical innovations like on-site recycling or ecological sanitation. The national government in parallel embarked on a far-reaching marketization reform, which aimed at breaking up some of the old institutional rigidities in the water and other infrastructure sectors.

555 In theory, it makes sense to assume that China was in a prime spot to transition to a
556 new socio-technical configuration in the water sector that would reflect its particular socio-
557 economic and material preconditions. However, as we will show, instead of nurturing some of
558 the (global) niches entailing potentially more sustainable configurations for the Chinese
559 context, the sector largely implemented large-scale hydraulic solutions and market-based
560 governance approaches, which are both commonly associated with the global water regime (cf.
561 section 4.1).
562 Our empirical illustration is based on extensive secondary data analysis and qualitative
563 expert interviews carried out by the authors in several prior research projects (Binz, 2008; Binz
564 et al., 2012; Binz et al., 2016a; Binz et al., 2016b; Fuenfschilling and Truffer, 2014). Data on
565 the global regime structure was derived from existing literature, as well as from qualitative
566 content analyses of political reports and newspaper articles in Australia, Europe and the USA
567 (Binz et al., 2016a; Fuenfschilling and Truffer, 2016; Fuenfschilling and Truffer, 2014).
568 Transition dynamics in China were in turn analyzed with secondary data analysis as well as
569 qualitative expert interviews with 40 key stakeholders from companies, the authorities, NGOs
570 and universities that were actively involved in the transformation of the Chinese wastewater
571 sector (Binz et al., 2012; Binz et al., 2016b).

572 ## 4.1 Global regime in the water sector

573 Water has repeatedly been characterized as a sector that is heavily affected by various
574 globalization processes (Gottlieb, 1988; Lieberherr and Fuenfschilling, 2016; Molle et al.,
575 2009). Multinational companies like Veolia, Suez, or GE occupy the lead-firm position in the
576 sector's GPN. They have accumulated vast financial resources, control suppliers in hierarchical
577 value chains and are able to provide turnkey solutions for the water and wastewater
578 infrastructure of entire cities in developed and developing countries, including after-sales
579 services and operation. Private engineering consultants like Black&Veatch or CH2M Hill are
580 advising governments on how to construct water systems, while international development
581 and investment banks (World Bank, Asian Development Bank, etc.) provide extended credit
582 lines for infrastructure projects. INGOs like the International Water Association (IWA), play a
583 central role in constructing the global 'water profession' and integrating technology expertise
584 from various places around the world by organizing working groups and conferences[1]. Overall,
585 while the concrete governance and regulatory frameworks of water sectors differ from place to
586 place (Lieberherr, 2012), the underlying regime rationality is surprisingly similar, gravitating

[1] See e.g. the IWA's 'young water professionals' platform; http://www.iwa-network.org/young-water-professionals/

around large-scale, centralized infrastructure, and operation and control in variegated 'public-private partnerships'.

As outlined above, three ideal-type institutional rationalities have been identified in the global water regime (Fuenfschilling and Truffer, 2014). The historically most sedimented rationality was termed the 'Hydraulic Logic'. It describes the logic behind traditional water infrastructure that is based on large dams, extended water and wastewater pipes, centralized operation and considerable influence by public authorities and the civil engineering profession (ibid.). Values such as security of supply, equity and technological efficiency are central for this rationality (see figure 1). Until the 1970ies, most water sectors in developed countries followed this regime and public utility-based, centralized infrastructure systems diffused globally at a massive scale.[2]

By the early 1970s, two competing rationalities emerged that increasingly challenged the taken-for-granted status of the 'Hydraulic Logic': the 'Water Market Logic' with a focus on economic efficiency and the 'Water Sensitive Logic' with an emphasis on environmental sustainability. In the former, economists pushed for neoliberal deregulation and privatization and re-conceptualized water as a marketable economic commodity. While infrastructure is still based on extended centralized piping networks, control is relegated from state monopolies to private actors. Market mechanisms, corporatized utilities, and multinational engineering companies play a key role in governing the sector. Core values are related to economic efficiency and rationalization, while end users are framed as regular customers that pay for the full costs of water services.

The 'Water Sensitive Logic', in contrast, embraces the thinking of environmental groups that also emerged around the 1970ies. Key values here are community-based reciprocity, conservation and environmental sustainability. Corresponding infrastructure projects advocate decentralized, closed-loop and natural systems that make the construction of large dams and sewer systems obsolete (Brown et al., 2008). Governance systems are decentralized and relying on local communities as well as small-to-medium enterprises that provide fit-for-purpose technologies. While all three institutional rationalities co-exist nowadays in the water sector, the hydraulic and to some degree the market-based logic still largely dominate the activities in this socio-technical system (Lieberherr and Fuenfschilling, 2016).

In the remainder, we will use the case of the Chinese water sector to illustrate the process through which a dominant regime rationality may diffuse in space. In principle,

[2] For instance, between 1950 and 2000 substantial investments in dams have been made worldwide: on average, two new dams were built each day, increasing the number of dams from 5000 in 1950 to 45'000 by 2000. In addition, irrigated areas doubled from 140 million hectares to 280 million hectares (Molle et al., 2009, referring to the World Commission on Dams).

transition literature expects emerging economies to be in a relatively favorable position to implement new (and potentially more locally adapted/sustainable) sector configurations (Berkhout et al., 2010; Binz et al., 2012). Many of their industrial sectors are just emerging, their infrastructure systems have not materialized yet, and regulations and governance systems are in a fluid or transitory state, thus allowing for quicker and more radical change than the locked-in socio-technical systems in developed economies (Angel and Rock, 2009; Rock et al., 2009).

Yet, empirical research consistently shows that latecomer countries are surprisingly unlikely to leapfrog to more innovative technologies and infrastructure systems (Gallagher, 2006; Rock et al., 2009; Sauter and Watson, 2008). More often than not, they embark on socio-technological trajectories that emulate (and thus reproduce the flaws of) the dominant regime in developed economies (ibid.). The example that will be in focus here are Chinese cities that built up water-intensive centralized wastewater infrastructure. We will illustrate how the global regime rationality influenced a process that at the surface looks like an essential local problem: Organizing wastewater discharge in China's booming megacities.

4.2 China in the 1980s and 1990s – Window of opportunity to develop a new sanitation regime

China considerably expanded its wastewater infrastructure between the late 1970ies and 2015. Even though basic water supply systems, sewers and dams were constructed in the communist era, urban wastewater infrastructure was largely dysfunctional before the 1970ies.[3] By 1990, the (official) overall wastewater treatment rate in China reached only 10% (Zhong, 2007) and few cities had fully functional water supply systems in place (Zhao 2015). With Deng Xiaoping's opening up policy, China's economy started booming, urbanization reached two-digit rates and urban sanitation became an increasingly pressing policy priority.

High investment rates from the mid-80ies allowed for experimentation with novel socio-technical configurations that would reflect China's particular local circumstances, in particular its pressing water scarcity. At the outset of China's massive infrastructure build-up campaign, the question how its future wastewater infrastructure would look like was thus essentially open. Given the obvious limitations of centralized wastewater infrastructure discussed above, in the mid-80ies several city regions started experimenting with alternative sanitation systems that would treat sewage directly at the source and make it locally available for non-potable reuse (Binz et al., 2016b; Li et al., 2013; Mels et al., 2007; Wang et al., 2008).

[3] E.g. Beijing opened its first sewage treatment plant only in 1990 (Zhao 2015).

One notable example was the city government of Beijing, which introduced a regulation to implement on-site treatment systems in major hotels, schools, government buildings and in the booming residential development zones at the outskirts of the city (Binz et al., 2016b; Mels et al., 2007). Other examples were the cities of Xi'an, which experimented with semi-centralized wastewater recycling systems (Wang et al., 2008; Wang et al., 2011; Zhang et al., 2010) and Kunming, which participated in a large international pilot study for no-mix sanitation systems (Medilanski et al., 2006). Throughout the nineties, the relevant Chinese firms, universities and city governments gained high visibility and got embedded in an international network ('global niche') of technology experts and consultants that were trying to establish a more flexible, decentralized and water-sensitive rationality in the urban water sector (Binz et al., 2014; Binz et al., 2016b).

In the early 90ies, China arguably had a unique window of opportunity to leapfrog the hydraulic logic and establish a more water sensitive or even an entirely new institutional rationality that would reflect the countries particular material and institutional preconditions. Yet, while various niche experiments showed promising performance (Wang et al., 2008) and related local water companies quickly reached a globally leading position (Yap and Truffer, under review), China's wastewater sector did ultimately not develop a novel regime rationality, but embarked on a development process that emulated and diffused conventional centralized wastewater infrastructure at a never-seen scale (see Figure 3).

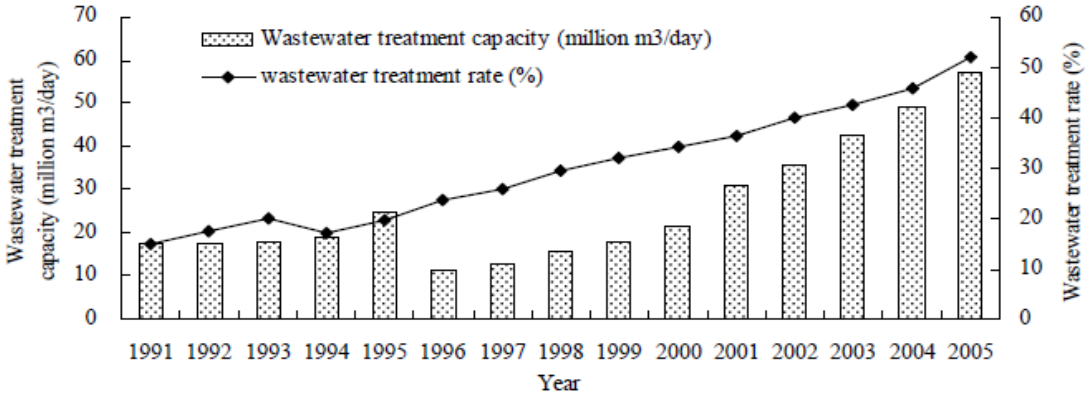

Figure 3: Build-up of China's wastewater infrastructure
Source: MOC, China Urban Construction Yearbook 2005, cited from (Zhong, 2007: 8)

4.3 How global regime rationalities influenced China's transition trajectory

The influence of the proponents of alternative socio-technical systems started fading in the 90ies, when China embarked on widespread marketization reforms and invited external expertise to support its infrastructure build-up. The sheer scale of the urban wastewater problem in China got increasingly visible through major pollution accidents in the 90ies and

early 2000s and policy makers were pushed to quickly address the problem (Yu, 2011). In the eyes of key decision makers socialized in China's authoritarian governance system, domestic actors pushing for water-sensitive solutions were not considered legitimate enough. They rather preferred external expertise, embedded in a nexus of MNCs, consultants and investment banks that had historically aligned in a mature GPN structure and which could provide highly legitimate and 'modern' turnkey solutions. With Deng Xiaoping's opening up policies, from the early 80ies, expertise on the planning, design and operation of wastewater infrastructure quickly started flowing in through project financing and consulting activities by the World Bank, the Asian Development Bank, as well as various foreign development agencies and consultants (Zhao, 2015; Zhong, 2007). Between 1984 and 1992 alone, 150 water projects (costing about 1.8 bn. US$) were funded through long-term development loans from outside China (Zhao, 2015: 74).

Foreign loans and development aid came with consulting mandates that were subcontracted to foreign water MNCs and engineering consultants. Subsidiaries of the French water MNC Suez started their first activities in China already in 1975, and subsidiaries of Veolia followed suit in the early 1980ies (Zhong, 2007). Also Thames Water and water equipment suppliers from the UK and US entered China in the late 80s, but as the Chinese government restricted direct private sector participation, all of them initially limited their activities to consulting donor agencies and local governments or providing general support in project management (ibid.). The first foreign direct investment by a multinational company (Suez' investment in the Tanzhou Water Supply Project) happened only in 1992 (Zhao 2015), yet at that time, dominant players of the global regime had already established the cultural-cognitive rationality of 'modern' wastewater infrastructure in China's central decision-making circles.

From 2001, China embarked on a targeted 'marketization reform' in the water sector and joined the WTO which meant that some large water project tenders now had to be announced globally (Browder et al., 2007; Fu et al., 2008). A comprehensive reform program was implemented which emphasized three main areas: marketization, privatization and decentralization of economic and managerial responsibilities (Zhao, 2015). Subsequent shifts in priorities of national and regional policies were justified on the grounds that foreign investors would "*bring advanced technology and management experience to positively influence the long-term development of China's water and wastewater treatment sector*" (U.S.Department of Commerce, 2005: 28). Changes in governance indeed quickly improved urban water infrastructure and attracted considerable private investment (see Figure 4). Yet, they also implied that urban governments to some degree transferred control on infrastructure planning and investment from local constituencies to global regime actors.

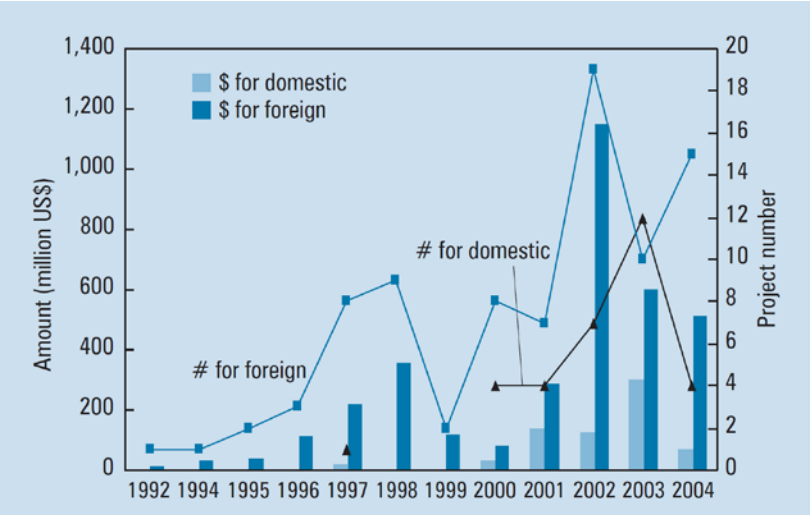

Figure 4: Private Sector Investment in Chinese Water Sectors
Source: (Browder et al., 2007: 120, cited from Global Water Intelligence 2005)

As a result, various contradictions became visible in the governance of China's wastewater sector: In the case of Shanghai, the city government decided to sell a 50% share of the state-owned Shanghai Pudong Water Supply Corporation to Veolia in 2002 (Lee, 2006). Henceforth, the water treatment system of more than half a million Shanghainese would be renewed, organized and controlled by a foreign lead firm in the water GPN, which would also directly collect user fees (ibid.). This step was unheard of in China and happened without explicit support by the central government. Still, in Shanghai's local policy context, resourceful private actors and urban policy makers decided to circumvent national regulations in favor of a quick and modern solution. Several other prestigious public-private-partnership projects followed suit in Shanghai and other Chinese cities, all of which implemented similar large-scale, centralized infrastructure systems. The adaptation of local institutional structures to the strategic needs of global regime actors exemplifies what GPN literature increasingly terms the 'dark side of strategic coupling' (MacKinnon, 2012). Lee (2006) concludes for the case of Shanghai that foreign donors and MNCs' participation "*precipitated the adoption of […] institutional change in the Shanghai water sector through many large-scale water projects […]. Such institutional reform brought obligations that the Shanghai government had to observe when it benefited from development loans through the international agencies.*" (Lee, 2006: 54)

Shanghai is an emblematic example for the broader process through which foreign actors established dominant regime rationalities in China: First and foremost, French and British water engineering consultants played a prominent role in importing dominant cognitive frames of 'successful' wastewater projects to China. Lee (2007) estimates that by 2007, Degremont (a subsidiary of Suez) alone was directly or indirectly involved in the planning, consulting and construction of 10% of all water and wastewater treatment plants in

China. Other important actors were Veolia, Mott MacDonald, Thames Water, and semi-private Chinese investor companies like the Youlian Consortium, the Beijing Sound group, or the Shanghai Construction and Engineering Group (ibid.). In most cases, Chinese city governments established long-term contracts with these companies to invest in and build treatment plants, operate them (usually for about 30 years), and ultimately transfer the systems back to the local utility. Negotiations about these public-private partnership contracts and the concrete technological solutions were held at highest government levels, drawing on the resource endowment and social prestige of key actors in the water GPN. In one of our previous studies, the executive director of a foreign water equipment supplier described the lobbying process as follows: "*We basically invited a bunch of highly influential policy makers to Shanghai. Senior level, NDRC and top national government. We put them in a five star hotel for two days to wash their brains. You know, making them use our technology"* (Binz, 2008, 143).

A considerable share of China's early wastewater infrastructure projects were furthermore supported by financing and technology consulting from the World Bank, Asian Development Bank, the Japan Bank for International Cooperation (JBIC), as well as several foreign development agencies (Zhao, 2015). Browder et al. (2007: 108) estimate that overall 20-30% of the initial investment in Chinese wastewater infrastructure between 1990 and 2005 originated from the private sector and international development banks. Development banks provided extensive loans to implement projects together with local and international partners and took an active stance in promoting key regime features like full-cost recovery, centralized operation and control as well as the privatization of infrastructure development (Browder et al., 2007; Lee, 2007). Incongruence of the proposed large-scale centralized infrastructure systems with local water scarcity or regulative conditions e.g. in wastewater projects in Xi'an or Chengdu, was not strongly problematized. The projects were rather framed as decisive leaps in the modernization and economic development of the respective regions and used by local government officials to legitimize their political program and promote their careers (Browder et al., 2007).

Finally, also informal technology and knowledge communities played a role in influencing basic assumptions about valuable transition trajectories for the Chinese wastewater sector. Civil engineering expert groups in the IWA organized a series of high-profile conferences and workshops to discuss the applicability of foreign 'best practices' in China. The world's most influential trade show for water, sewage and environmental technologies (IFAT) developed an annual branch conference in Shanghai.[4] Chinese technology experts were invited

[4] See http://www.ie-expo.com/

to tour Western treatment plants and research groups from Qinghua and other prestigious Chinese universities got integrated in large international research projects on (conventional) wastewater technology (Binz et al., 2014).

In summary, opening China's wastewater sector to private investors, consultants and wider expert communities in the existing water GPN between 1990 and 2005 not only enabled very fast infrastructure build-up, but also induced far reaching institutional rearrangements in favor of conventional, centralized wastewater infrastructure and a hydraulic/market- based institutional rationality in China. Despite China's unique cultural, material and socio-political preconditions and promising developments in alternative bottom-up niche activities, its wastewater sector now follows a development trajectory, which is hardly distinguishable from the global regime rationality in Western countries.

Actor networks following the two other – less deeply institutionalized – rationalities balanced the inflow of global regime logics only in the early phases, but ultimately lacked agency in establishing, legitimizing and defending an alternative, potentially more 'water-sensitive' and sustainable trajectory. In particular, actors pushing for water-sensitive approaches also deepened their cooperation with international NGOs and established lighthouse projects in Xi'an, the Olympic park of Beijing or Eco-Cities like Ordos or Tianjin. Still, despite quite substantial lobbying efforts and institutional work at a city and regional level, these constituencies did not reach an impact comparable to the supporters of conventional infrastructure, which was backed by MNCs, development banks and external technology, management and investment experts in the water GPN. By the end of the 2000s, even key Chinese companies like Beijing Origin Water, which initially boomed in the alternative on-site recycling market, turned their main activities to conventional centralized infrastructure (Yap and Truffer, under review).

5 Global socio-technical regimes – contours of a research agenda

This short case study illustrates that key decisions on the transformation of the wastewater infrastructure in China were not driven by adaptation of existing water technologies to the local context. Rather, the chosen solutions indicate a high congruence with what is commonly associated with the global water regime. This despite the fact that at first glance, China appeared to be relatively independent in choosing its development trajectories. However, the supporters of alternative socio-technical configurations, i.e. of (global) niches that might have provided better adapted solutions for the Chinese context, could ultimately not prevail against the institutional pressures exhibited by the global regime and its structurally well positioned actors, such as MNCs, development banks, and various national and international academic and non-governmental expert communities.

When analyzing sectoral transition dynamics in specific places, it is thus important to understand how decisions are influenced by institutional rationalities and actor networks that expand well beyond the immediate territorial borders. In the case described above, the actors that lobbied for alternative pathways did not only face resistance from national and regional selection environments. They were ultimately challenging a deeply sedimented global regime backed by powerful international actor networks with extensive definitional authority and access to critical resources and top decision-making circles. In hindsight, efforts to build local and national constituencies around alternative development trajectories were bound to fail, as they did not include strategies to challenge the global regime and its structuring powers. Further developing the concept of global socio-technical regimes thus holds substantial promise in improving the conceptualization of transition dynamics. We see five main areas where our perspective could contribute novel perspectives.

1) Regime transformation: First and foremost, a spatially open and institutional conceptualization of socio-technical regimes offers new insight into potential sources of innovation and change. Institutional theory suggests institutional plurality and complexity as a key starting point for institutional change (Friedland and Alford, 1991; Greenwood et al., 2011; Kraatz and Block, 2008; Thornton et al., 2012). The global regime concept specifies various forms of such institutional plurality. On the one hand, we conceptualized regimes as being semi-coherent, i.e. as potentially incorporating elements from ideal-typically different institutional rationalities. Hence, there is always the inherent likelihood for contradictions and conflicts, which can be seen as an opportunity for change, since actors are able to recombine different rationalities and hence broaden their scope of legitimate agency (De Vaan et al., 2015; Fuenfschilling and Truffer, 2016).

On the other hand, niche-regime interactions provide another well-established source of institutional complexity and change. With a global conceptualization of regimes and niches in mind, those dynamics can be specified in more detail. One important type of institutional plurality stems from the contradictions resulting from the interplay between global institutional rationalities and local material and institutional preconditions, similar to what is usually discussed under the header of glocalization (Courchene, 1995; Drori et al., 2014; Ritzer, 2003; Robertson, 1995). Global models are always translated, de-, and re-contextualized in a specific location with local particularities, such as local cultural or religious customs, laws, values, regulations, practices or material preconditions (Coe and Yeung, 2015; Monstadt and Schramm, 2017). While our case study did not highlight this process in much detail, the tension between global rationalities and local settings may play a key role in inducing innovation processes. The resolution of conflicts between the global rationality and local particularities might even bring about novelties that become relevant on a broader scale if they are fed back

to the global regime. In addition, mere copy mistakes might lead to innovation. They commonly happen when trying to emulate global regime rationalities in order to signal legitimacy. Future research should thus investigate the spatial variations of regimes as sources of innovation and change (Coenen et al., 2012; Raven et al., 2012).

The enactment of global regime rationalities thus somewhat paradoxically supports isomorphism while also bearing opportunities for change. Where, why and how isomorphism or divergences are created is an open empirical question. Considering transition pathways, the reproduction mechanisms of global regimes, on the one hand, are prone to entrench existing socio-technical configurations by diffusing them at an international scale. On the other hand, if a more sustainable solution is developed and picked up, global regimes could in principle be very effective in diffusing it to various parts of the world. This underexplored tension between isomorphism and local variation in global regimes warrants an own stream of research.

2) Agency and power: Understanding regimes as global institutional rationalities has implications for the conceptualization of agency and power in transition studies. Institutional concepts such as embedded agency, institutional work or the notion of institutional entrepreneurship have already been fruitfully used to understand the possibilities of actors to shape institutional environments and overcome the structure-agency paradox (Fuenfschilling and Truffer, 2016; Smink et al., 2015). Taking an institutional perspective on regimes seriously, it becomes crucial to study how actors engage in the (re-)production of cultural-cognitive regime structures.

Our conceptual approach helps to identify specific actor types and constellations that are crucial in this process and it thus adds to the existing discourse on agency and power in transition studies (Avelino and Rotmans, 2009; Geels, 2014; Kern, 2011). Several actor types seem specifically important in the process of institutionalization, i.e. in manifesting and translating rationalities into binding regulations or material practices. At a general level, actors may exert pressures through coercion, standardization or mimesis. This includes actors with legislative powers such as nation states and IGOs in the case of coercive pressures; various types of professional and standardization actors for normative pressures; and leading firms and legitimate experts for mimetic pressures. Our case study hinted to the important role of so called ‘rationalized’ or ‘generalized others’, such as INGOs, professions or expert consultants, in writing the scripts and frames for global regimes that various actors have to adopt in order to appear legitimate. This focus on actors that have general definitional authority in producing alternative rationalities might be critical in regard to understanding the origins of transformative change.

Furthermore, there are theoretical arguments that draw on a range of non-institutional sources for agency. We argue that an important source for agency lies in an actor’s position

within a social network, e.g. a sector's GPN/GVC. Merging insights from institutional and network theory shows how intertwined actors and institutions are (Beckert, 2010a; Mizruchi, 1994; Powell et al., 2005; White, 1992). It thus seems highly promising to further investigate how social networks and institutional rationalities co-evolve within a socio-technical system. Are networks, i.e. actors, the carrier of institutions and thus precede institutional change? Or is institutional maintenance and change also visible if there is no change in actor structure? If not through actors, how else are dominant institutional rationalities transported (e.g. through materiality/technologies or discourses)?

Focusing on the structural position of actors in networks (e.g. within global production networks) could enable a conceptualization of agency as a result of network embeddedness and positionality instead of actor characteristics, skills or entrepreneurship (Callon, 1998; Granovetter, 1985; Granovetter and McGuire, 1998). Arguments referring to social structures as explanatory variables, e.g. following scholars like Granovetter (1973) and Burt (1992), have to date been rather neglected in transition studies. This comes despite the fact that it could lead to new insights regarding how social and institutional structures co-evolve over time. Agency could then be a relational quality stemming from an actor's position in a sector's social structure that is strongly internationalized and that operates within a common reference frame, i.e. the global regime of a socio-technical system.

From a global regime perspective, actors occupying a central network position in a GPN (such as water MNCs) can be viewed as most powerful in influencing key institutional rationalities, yet we would also assume them to be most deeply embedded in the dominant regime. Actors in structurally more peripheral positions (e.g. proponents of on-site water recycling) may in turn have less direct influence on decision makers and the dominant technological trajectories, but be freer to experiment with alternative socio-technical configurations. Transitions could accordingly be modelled as peripheral actor networks in a GPN moving to a more central network position over time. How much agency actors in peripheral network positions have may in turn be directly related to how hierarchical ('captive') the overall network structure of the GPN is. In the water sector's relatively centralized network structure with strong power asymmetries, transitions may take longer than in a relatively flat ('relational') GPN. Yet, how, when and where exactly power differentials and agency may lead to a successful transition is an open question that warrants future research.

3) ***Niche-regime interaction***: Our approach implies that the multi-scalar interactions through which socio-technical regimes and niches develop, diffuse, get maintained and dissolve, moves center stage. Consequently, transitions should be interpreted as an outcome of contestation between regimes and niches in complex spatial setups (Coenen et al., 2012; Murphy, 2015). This has far-reaching conceptual implications.

First, it implies that the idea of niches as protective spaces has to be reinterpreted. If transitions are conceptualized as shifts in the dominant institutional rationality of an internationalized socio-technical system, protected spaces will not be limited to one specific spatial context. They will rather emerge from co-evolution in complex 'place bundles' (Pierce et al., 2011) that dynamically advance over time. I.e. we would not frame the ongoing energy transition as a patchwork of national initiatives in Germany, the UK or China. We rather see it as a co-evolutionary dynamic between niche processes in all these places that in their complex interaction form a global niche (or maybe already a proto-regime) which is challenging taken-for-granted beliefs on how energy should be produced, distributed and governed in various places around the world (Carvalho et al., 2012; Quitzow, 2015).

Who is involved or excluded from transition processes is not a question of 'national' regime vs. 'local' niche players anymore, but essentially an issue of the social construction of scale and relational place-making (Murphy, 2015). In some cases, both regime and niche rationalities might predominantly stem from internationalized networks, but get manifested in one or a few territorial arenas. The power of local players in influencing a local transition process may accordingly be more or less limited. Our empirical case showed that the city government of Shanghai got omitted to some degree from critical decisions on how the city's future water infrastructure should be designed. Sengers and Raven (2015) equally showed that city government of Bangkok had limited agency in adapting a traffic system solution implemented by external experts to local cultural conditions. Additional research is needed to assess in detail how both 'regime' and 'niche' actors may mobilize transnational networks in a transition trajectory and why and how key framing struggles may manifest themselves in specific geographic contexts like cities. Various connections to human geography could (and should) be explored in this venture (Murphy, 2015).

Finally, a key empirical question that warrants future research is what type of regions, cities, countries or place bundles are most likely to succeed in radically deviating from path-dependent regime rationalities and embarking on alternative trajectories. We hypothesized that latecomer regions with lacking material infrastructure provide fertile ground for experimentation. Yet, the case study showed that pre-existing institutional structures (like China's authoritarian one-party system) may still structurally bias decision-making toward favoring well-established (here: centralized) regime solutions. Another working hypothesis is that internationally well-connected city regions with proactive transition policies or regions with particularly liberal cultures provide promising seeding grounds for transitions, while peripheral regions that are in a captive network position in GPNs may be more dependent on complying with global regimes. Much more research is clearly needed to further explore the relationship between historically grown local institutional structures and dynamically evolving global niche and regime structures.

4) ***Policy implications***: Taking a multi-scalar perspective on sustainability transitions also sheds light on the complexities of the governance of transitions. In sectors with strong global regimes, national policy making has clear limits in steering a transition trajectory. The internationalized actor structure of many regimes, as well as the internationalized actors themselves, typically are not bound to any national regulation. More accurately, they are able to choose their location according to their preferences, which makes it harder for the state to intervene, i.e. apply the usual incentives for behavioral change, such as taxes, subsidies, etc. The big policy question thus becomes: how can policy intervene in a global regime? What kind of global governance arrangements would be able to target and steer the actors reproducing the current unsustainable regimes? While some experimental global governance arrangements exist in the form of climate agreements, questions remain on their effectiveness and on whether they could be reproduced in other sectors (e.g. water) or for reaching the UN's sustainable development goals.

Here we see potentially fruitful overlaps with other disciplines that study the creation, transformation and diffusion of global paradigms. Development studies, in particular global development perspectives (Gills, 2017; Hettne, 1995) and post-development approaches (Escobar, 2011; Rahnema and Bawtree, 1997), offer many insights into the role of global (often specifically Western) economic models and cultural paradigms for the development and transformation of various developing and emerging economies around the world (Scholte and Söderbaum, 2017). Studies especially illuminate the power of different kinds of actors in creating and diffusing a certain (often Western and hegemonic) agenda across the world (Nilsson, 2016).

Actors have increasingly been found to be polycentric, spanning across multiple scales (local to global) and sectors (public to private) and bringing with them very diverse understandings, expectations, discourses and motivations. Coordination of action, especially if one has certain normative targets like the SDG in mind, thus becomes a very complex endeavor. Scholars have therefore suggested various concepts that discuss questions of governance of global issues, such as for instance 'multi-scalar meta governance' (Jessop, 2009) or 'regime complex' (Keohane and Victor, 2011). Also the idea of 'hypercollective action' has emerged, which proposes a new mode of production of global policies that accounts for the complexity of today's actor structure and suggests managing that complexity through a specific set of rules and agreements, norms and standards, systems of incentives, information and discourses as well as networks and partnerships (Severino, 2010). Insights from such studies can thus contribute to a better understanding of how global regimes can be managed and shaped, which actors have power and agency and thus how transitions can be governed and accelerated. Second, also the characteristics of global niches suggests that national industrial and

innovation policies may in many cases have unintended spatial spillovers (Binz and Truffer, 2017). For instance, recent research has claimed that cities become the places where system innovations are happening, and new socio-technical configurations emerge that then diffuse more widely (e.g. Frantzeskaki et al., 2017). Whether cities are conducive places for transitions in all sectors and how the many efforts of experimentation happening all over the world could be more fruitfully coordinated or aligned are still largely open questions. In general, the question is: How can the multi-scalarity of niche-regime interaction be reflected in national and supranational policy interventions? Effective transition policies would have to foster local-global niche activities while limiting – or even disrupting – the mimetic pressure stemming from global regimes. Mapping these global niche and regime structures in various sectors would be an important first step to defining a new set of globally coordinated transition policies.

5) Methodology: Last but not least, opening transition research to questions of spatial and institutional complexity has consequences regarding viable methodological approaches and research designs. This paper is a plea to complement the plentiful single case studies of socio-technical transitions at a country- to city-level with studies that consciously cross-compare cases in distant places or directly address actor networks and institutional change at supra-national levels. INGOs, global patent, trade and publication repositories, as well as international trade and migration statistics all provide databases that might be mobilized for an analysis of regime structures beyond single countries. Global actor structures may be visualized and analyzed with social network analysis while the impact of informal institutions may be isolated based on novel forms of comparative discourse analysis (see e.g. Fuenfschilling and Truffer, 2014; Ter Wal and Boschma, 2009; Van der Valk and Gijsbers, 2010). Future research in this field should also actively include emerging and developing economies and find new ways of assessing the agency of powerful incumbents. Ultimately, instead of analyzing in ever more depth how e.g. the energy transition differs between specific places, we propose an agenda that tries to understand why the barriers to sustainability transitions look so similar in many places around the world.

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