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Path Creation as a Process of Resource Alignment and Anchoring: Industry Formation for On-Site Water Recycling in Beijing

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abstract

Where and how new industrial paths emerge are much debated questions in economic geography, especially in light of the recent evolutionary turn. This article contributes to the ongoing debate on path creation with a new analytical framework that specifies the formation of *generic resources* in embryonic industries. It suggests that path creation processes are not only conditioned by preexisting regional capabilities and technological relatedness but also by the way firm and nonfirm actors mobilize and anchor key resources for industry formation. Our framework elaborates on the early industry development phase, extending the focus on regional knowledge spillovers in evolutionary economic geography (EEG) literature with recent insights on industry formation dynamics from innovation studies. It understands early path creation as conditioned by four systemic resource formation processes—knowledge creation, investment mobilization, market formation, and technology legitimation—that can be mobilized both from inside or anchored from outside the region. The use and value of the analytical framework is illustrated by a case study on on-site water recycling technology (OST), based on interviews with 40 experts in three Chinese city regions. The findings suggest that, despite possessing the least favorable initial conditions, a sizable OST industry developed only in Beijing. This is explained based on the specific anchoring process of the four key resources in the early development stage of the industry. Our results imply that EEG would profit from incorporating a broader set of variables than knowledge-based relatedness in explanations of regional industrial path creation.

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In the wake of an evolutionary turn, economic geography has witnessed lively debates on path dependency and the determinants of regional path creation (Boschma and Frenken 2006; Boschma and Martin 2010; Essletzbichler and Rigby 2007; Martin and Sunley 2006). In particular, the fundamental question where and how new industries emerge has regained interest in the relevant theoretical debates (Martin 2010, 2011, 2012; Simmie 2012b). Recent evolutionary studies strongly emphasize technological relatedness across regional industries, combinatorial knowledge dynamics, and branching processes as key explanatory factors for where and how new industries develop (Asheim, Boschma, and Cooke 2011; Neffke, Henning, and Boschma 2011; Boschma and Frenken 2011a). Regions are assumed to branch into technologically related fields in a path-dependent related diversification processes (Martin 2012; Neffke, Henning and Boschma 2011; Cooke 2004; Boschma and Frenken 2011b). Where new industries emerge is strongly contingent (though not predetermined) on the preexisting industrial structure of regions.

This broad body of literature has shed new light on how and why *history matters* for innovation and regional economic growth (Martin 2010). Yet, its conceptual and methodological approach has recently also attracted several lines of criticism (Hassink, Klaerding, and Marques 2014; Henning, Stam, and Wenting 2013; Dawley 2014; MacKinnon et al. 2009), two of which will be taken up in this article: first, evolutionary economic geography's (EEG's) focus on technological relatedness downplays the influence of nonfirm actors, institutions, and public policy in creating and/or renewing industrial development paths in a region (Hassink et al. 2014; Dawley 2014; Asheim et al. 2013). By emphasizing organizational routines at the firm level and knowledge spillovers through spin-offs, labor mobility, social networking, or firm diversification, it tends to give partial accounts of the industry formation process that focuses rather exclusively on knowledge dynamics while ignoring the role of more collective and distributed action in creating and exploiting innovative opportunities in a region (Coenen, Benneworth and Truffer 2012; MacKinnon et al. 2009; Simmie 2012b; Dawley 2014; Tanner 2014). Second, by emphasizing *generic resources* (mostly sector-specific knowledge and skills) originating and evolving predominantly from inside the region, EEG risks incorporating a kind of regional fetishism (Martin and Sunley

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2006). As Asheim et al. (2013, 5) put it, in its current form, EEG is downplaying that 'global innovation network linkages in their various forms can contribute to the renewal, extension or even transformation of the regional resource base' and—as we argue—the development of new industrial paths.

To address these critiques and to help further specify the generic resources involved in early path creation, this article proposes a new analytical framework that explicitly includes firm *and* nonfirm actors; key resource formation and alignment processes (beyond knowledge dynamics); and, in particular, the decisive role of extraregional network connections in inducing new paths. We propose to conceptualize early path creation in relation to recent analytical frameworks from innovation studies and the literature on sociotechnical transitions, two fields that have extensively analyzed the early industry formation phase. Drawing on their insights, path creation is conceptualized as a sociotechnical alignment process where heterogeneous actor networks mobilize not only knowledge but also financial investment, market access, and technology legitimacy from both inside and outside the region. In order to account for the changing geographies of innovation in a globalizing knowledge-based economy, we argue that it is crucial to understand how extraregional resources influence the formation of specific regional growth paths and how resource formation and alignment processes get embedded in regional institutional contexts (Coenen et al. 2012). *Anchoring* of extraregional resources (Crevoisier and Jeannerat 2009) is thus an integral part of explanations of early path creation.

By developing this analytical framework, the article aims at generating more nuanced answers to the fundamental questions when (under what conditions) and how (through what kind of mechanisms) new industrial paths are created in regions (Boschma and Martin 2010; Dawley 2014; Tanner 2014). It hypothesizes that endogenous development factors—like preexisting capabilities and technological relatedness—induce new paths only if they get integrated in a broader resource formation and alignment process in the global innovation system emerging around a new technology. In particular, the coupling between (spatially extensive) technology-specific actor networks and institutions and the actors embedded in a given regional innovation system are key to understanding how and where new industries form (Oinas and Malecki 2002).

In order to illustrate the use and value of the framework, we chose the case of an emerging industry in the field of urban infrastructure technology, namely on-site water recycling technology (OST) in China. Innovation success in this case not only depends on adequate knowledge production but requires the involvement of a broad array of actors and alignment with manifold institutional structures. This sort of institutionally complex case is well suited to develop our analytical framework that includes additional explanatory dimensions to knowledge and technology relatedness. Yet, in the discussion, we will argue that the conceptual framework derived from this extreme case is of relevance beyond this single case; also for path creation processes in industries that rely more strongly on the generation of new knowledge stocks. The empirical analysis shows that Beijing was the only Chinese region that successfully created an embryonic path in this industry. Its success is remarkable, given that the region provided relatively unfavorable initial conditions. Two other regions, Xi'an and Shanghai, provided more promising generic resources with regard to technological relatedness, but both failed to create an OST industry. Comparing Beijing's success case with two unsuccessful examples will illustrate the contributions of our framework to knowledge- and relatedness-based explanations of path creation.

The remainder of the article is structured as follows. The next section reviews the current debate in economic geography on (regional) path creation and identifies gaps in its conceptualization of the early path creation phase. This is followed by a section that introduces elements from sociotechnical transition and technological innovation system (TIS) literatures for an analytical framework that is based on resources, alignment processes, and anchoring. The consecutive two sections present data set and methodology and apply the framework to the emerging OST industry in Beijing, Xi'an, and Shanghai. The conclusions further elaborate how the proposed framework adds new elements to EEG's path creation concepts.

Path Creation in EEG

Over the last two decades, path dependency and organizational routines have become two key building blocks in EEG's theorizing of industrial path creation (Boschma and Frenken 2006; Martin 2010; Grabher 2009; Boschma and Frenken 2011c). In contrast to institutional and neoclassical approaches, EEG understands path creation as a branching process out of a region's preexisting industrial structure and organizational routines (Boschma and Frenken 2006; Boschma and Frenken 2011b; Trippl and Tödtling 2007). Similar to evolutionary economics, it starts from the assumption that firms consist of bundles of organizational routines,[1] which get replicated and altered in a path-dependent process over time (Nelson and Winter 1982): as new technological or market opportunities emerge, new firms, spin-offs, or subsidiaries of existing firms get created that try to exploit these new opportunities. These new organizations inherit the organizational routines from their predecessors and recombine them with related routines needed to exploit the product innovation (Nelson and Winter 1982). Over time, market competition acts as a selection environment that only lets firms with the most successful routines survive (Boschma and Frenken 2006). Empirical research shows that routine replication and recombination

[1] Organizational routines consist mostly of experience-based (learning-by-doing) knowledge and tacit knowledge.

have a strong regional bias: spin-offs often locate close to their parent organization (Klepper 1996); tacit knowledge spillovers occur more often among geographically proximate actors (Breschi and Lissoni 2001); and labor mobility is often confined to a given labor market area (Frenken and Boschma 2007). Overall, in EEG's view, regional spillovers from related, yet not too proximate industries endogenously induce new industries in a region through processes of recombinatorial innovation (Neffke, Henning, and Boschma 2011; Boschma and Frenken 2011b).

The merits of this approach in assessing the determinants of regional development have been widely demonstrated in a quickly growing body of literature (Boschma and Frenken 2006; Neffke, Henning, and Boschma 2011; Boschma and Frenken 2011b). Several empirical studies have shown that regions tend to branch into technologically related fields and that related and unrelated variety in their structural composition have positive effects on regional development and employment (Frenken, Van Oort, and Verburg 2007; Boschma, Minondo, and Navarro 2012). Yet, whereas this perspective has proven useful in assessing the long-term, incremental evolution of regional industrial compositions, it has more problems in explaining why new paths typically emerge only in a few specific regions while they fail in others that provide equal (or even better) initial technological relatedness and organizational routines.

This limit of explanatory power in our view stems from gaps in EEG's conceptualization of the very early stages of new path creation (Martin 2010); the early phases of radically new paths are characterized as *windows of locational opportunity* (Storper and Walker 1989; Boschma 1997; Scott and Storper 1987). Since early industries rely on generic resources that are spread more or less ubiquitously in space, many regions have the same initial potential of hosting them (Boschma 1997). First, companies of a new industry thus locate randomly in one or several regions. Later, when companies have constructed a supportive context in specific regions, the new industry gets locked in to a path-dependent development trajectory in specific places or regions (Storper and Walker 1989). In this perspective, historic accidents and the spatial distribution of *generic resources, capabilities*, or *assets* explain early company's locational decisions, whereas the later probability of regions for developing a new industrial path depends on the emerging sector's interventions in the regional institutional contexts and supplier networks (Boschma 1997; Storper and Walker 1989; Boschma and Frenken 2009).

The process through which actors in a new technological field transform generic resources to new industries or induce regional industrial paths that deviate from existing trajectories is not conceptualized in much detail. Also, the set of resources that the actors might draw on in the early path creation phase are not further specified. For example, Hidalgo et al. (2007) talk broadly about capabilities (comprising mostly physical infrastructure, institutions or product-related skills or norms), whereas other authors use assets, resources, or localized capabilities to describe the regional tacit knowledge and competence base as well as institutional environment that precede new regional paths (Boschma and Frenken 2006; Maskell and Malmberg 1999). Thus, although evolutionary theorizing highlights how, '*once selected*, a new form of economic development, structure or technology may generate its own self-reinforcing processes [. . .], it is largely silent on the issues of *how and where* that novelty comes from, or why one form of novelty gets selected over another' (Martin and Sunley 2006, 407; emphasis in original).

Several authors now argue that more dynamic theories of path dependence are needed, which explicitly unpack the mechanisms and processes that drive early regional branching and the emergence of new paths (Simmie 2012b; Henning et al. 2013; Dawley 2014; Tanner 2014; Sydow et al. 2012; Strambach and Halkier 2013). We argue that existing evolutionary frameworks would have to be extended in two main respects: First, to better understand the key mechanisms underlying early industry formation, one needs to look beyond knowledge-based and firm-centric accounts to include distributed and embedded agency in the sociotechnical alignment processes in the region (Dawley 2014). In particular, we will argue that a specification of the generic resources that actors mobilize in early path creation processes would help us to better understand how routine diversification at the firm level coevolves with broader organizational and institutional innovation in the region. Second, to avoid regional fetishism, extraregional resources and the way they get accessed and anchored in these alignment processes needs to be an integral part of the respective explanatory frameworks (Tanner 2014; Vale and Carvalho 2013). The next two sections will elucidate these two arguments in more detail.

The Need to Look beyond Organizational Routines in Path Creation

Before venturing into further conceptual discussion, we define path creation as follows: 'A new path is created in a region if it contains a set of functionally related firms and supportive actors and institutions that are established and legitimized beyond emergence and facing early stages of growth, developing new processes and products' (Vale and Carvalho 2013, 1022). This definition is in line with several recent contributions in EEG, which argue that the recombination of firm-based organizational routines in a region coevolves with wider set of nonfirm actors (Tanner 2014; Gilbert and Campbell 2015), policymaking (Dawley 2014; Gilbert and Campbell 2015), as well as institutional contexts (Dawley 2014; Simmie 2012a; Garud, Kumaraswamy, and Karnøe 2010; Simmie, Sternberg, and Carpenter 2014). Several empirical studies also unpacked how entrepreneurial actors engage in path de-locking (Martin 2010), path plasticity (Strambach and Halkier 2013), or active path creation (Dawley 2014; Tanner 2014; Sydow et al. 2012; Garud et al. 2010).

In these institutional and often narrative-based perspectives on path creation, '"initial conditions" are not given, "contingencies" are emergent contexts for action, "self-reinforcing mechanisms" are strategically manipulated, and "lock-in" is but a temporary stabilization of paths-in-the-making' (Garud et al. 2010, 760). Path creation is an iterative construction process where networks of distributed actors jointly create new market segments and user profiles, adapt regulations, lobby for subsidies, or define new technical standards and thereby ultimately create the conducive environment that helps a new industry develop and prosper in a region (Garud et al. 2010; Garud and Karnøe 2003). New paths emerge not from external shocks but from the strategic agency in heterogeneous actor groups that jointly act upon locked-in structures and mobilize resources to create a new industry (Sydow et al. 2012; Karnøe and Garud 2012).

These perspectives respond to some of the criticisms on EEG raised above: they apply a pronounced process perspective on early industry formation, include nonfirm actors, and understand them as embedded in—and acting on—institutional structure. They also challenge the pervasive focus on knowledge dynamics: especially for industries that depend not only on codified scientific and technological (analytical) knowledge bases but also on the creation of (more synthetic) new service and business models or demand-side dynamics, institutional structures and policy intervention move center stage (Asheim, Boschma, and Cooke 2011; Dawley 2014; Martin and Moodysson 2013). Yet, this view, to date, has not created a detailed conceptualization of the resources and resource formation processes that the actors in an early industry can draw on (we will come back to this important caveat when defining our analytical framework). Also, similar to conventional path dependence theory, these approaches have mainly emphasized industry formation processes stemming from regional and national contexts and overlooked how extraregional connections influence industry emergence in space.

Specifying the Role of Extraregional Linkages in Path Creation

The strong emphasis on endogenous regional diversification and branching processes has readily been criticized (Tanner 2014; Trippl and Tödtling 2007; Vale and Carvalho 2013; Grillitsch and Trippl 2013). In a globalizing knowledge-based economy, systematic and permanent mobilization of knowledge has become a key process for innovation and industrial growth (Crevoisier and Jeannerat 2009; Foray 2004). Emerging industries are influenced by dense local knowledge networks as well as extensive global pipelines or *global buzz* (Vale and Carvalho 2013; Bathelt, Malmberg, and Maskell 2004; Maskell, Bathelt, and Malmberg 2006). Recent empirical studies, furthermore, underline the relevance of transnational entrepreneurship in early industry formation (Drori, Honig, and Wright 2009; Sonderegger and Täube 2010; Saxenian 2007). For example, Saxenian (2007) revealed that significant shares of Silicon Valley's new ventures are initiated by immigrating entrepreneurs. Sonderegger and Täube (2010) found that the explorative growth phase of Bangalore's information technology (IT) cluster was to a large degree supported by international diaspora networks. Where first companies of a new industry locate is thus not only contingent on a region's initial generic resources but increasingly by the regional actor's ability to mobilize external resources and anchor them in a regional entrepreneurial project (Martin and Sunley 2006; Crevoisier and Jeannerat 2009; Vale and Carvalho 2013).

With knowledge and entrepreneurial actors circulating in extensive international networks, 'there is a move from specialization within regional production systems to more specific regional knowledge and resources within multi-location networks of mobility and anchoring' (Crevoisier and Jeannerat 2009, 1225). Anchoring is not simply about bringing external knowledge to the region, but about 're-contextualizing and diffusing it in place, supported by capable entrepreneurs, universities, new organizations, policy action and flexible institutional settings' (Vale and Carvalho 2013, 1021). It is a process where extraregional knowledge gets accessed by regional actors and subsequently used to transform regional structures. Building a strong anchor for external knowledge requires the build-up of supportive regional environments and localized interdependencies between firm and nonfirm actors (Vale and Carvalho 2013). The process differs from embeddedness since it focuses on the movement of knowledge in space—away from the context where it was generated toward a new context where it interacts with existing knowledge and contexts in various ways (Crevoisier and Jeannerat 2009).

Summarizing this short discussion, an improved conceptual approach for path creation would enable a structured view on the distributed resource formation and alignment processes as well as on the anchoring of external resources in the early industry formation phase. In the remainder of the article, we will sketch out how recent conceptual ideas from transition studies and the TIS literature might provide promising first conceptual building blocks in this venture.

Analytical Framework: Key Resources and Anchoring in Early Path Creation

Transition and TIS studies emerged from evolutionary economics (Nelson and Winter 1982), innovation systems (Lundvall et al. 2002), and the social construction of technology literatures (Bijker 1995). Over the last 20 years, they integrated sociological and canonical understandings of path dependency in an elaborate research agenda that tries to understand the determinants of structural change in sociotechnical systems (Geels 2010; Markard, Raven, and Truffer 2012). Especially TIS literature has built up a rich body of conceptual frameworks to understand the embryonic phases of new industries and validated them with extensive empirical case studies, mostly in emerging clean-tech sectors (Carlsson and Stankiewicz 1991; Jacobsson and Bergek 2011; Coenen and Truffer 2012). TIS research focuses on three conceptual building blocks: actors, networks, and institutions (Markard and Truffer 2008; Bergek et al. 2008b; Hekkert et al. 2007). Actors are conceptualized in a broad sense to include companies (start-ups, spin-offs, and incumbents), universities, government agencies, intermediaries (e.g., industry associations, nongovernmental organizations), as well as end users. Networks include industry alliances, technical committees, working groups, regional innovation networks, or cluster organizations. The relevant institutional contexts are defined as the cognitive, regulative, and normative rules that enable and constrain actor behavior (e.g., laws, technology regulations, routines, markets, culture). New (technological) paths are assumed to emerge out of alignment processes between these dimensions (i.e., from actors accumulating in a new industry, forming new alliances and networks, and ultimately inducing changes to the relevant institutional contexts of the emerging industry) (Bergek et al. 2008b; Hekkert et al. 2007).

Resource Formation and Alignment Processes in a TIS Perspective

Even though it originates from the same family as national and regional innovation systems, the TIS perspective is, in various ways, distinct from these. In fact, its distinguishing characteristics respond to some of the evolutionary critiques that have been recently raised against regional innovation systems for being largely static and descriptive (Uyarra 2009). TIS literature complements a more structural approach to innovation systems, often found in national and regional innovation systems or the broader literature on territorial innovation models (Moulaert and Sekia 2003), by emphasizing alignment processes between institutions and technologies (Truffer and Coenen 2012). It does also not set a priori territorial boundaries, but follows actors, networks, and institutions to *wherever the analysis may lead* (Carlsson and Stankiewicz 1991). Another distinguishing feature is its process-based perspective on industry formation, conceptualized through a set of key system-building processes, as outlined in two programmatic papers by Bergek et al. (2008b) and Hekkert et al. (2007). The six key processes (knowledge creation, entrepreneurial experimentation, market formation, resource mobilization, creation of legitimacy, guidance of the search) can be interpreted as aggregates of the distributed agency in an emerging technological field, which form distinct resources for the actors involved in a new path as well as for the future evolution of the industry as a whole (Musiolik, Markard, and Hekkert 2012). Specialized technological knowledge and competencies, market niches, technology standards, or government subsidies are examples of such resources that are emergent properties of the systemic interplay among the key actors of a TIS; they develop through distributed agency in heterogeneous actor networks, benefiting all involved actors but cannot be easily controlled, owned, or provided by one single actor group (Bergek et al. 2008a; Musiolik et al. 2012; Bergek et al. 2015).

Rather than starting from routines that are manifested at the firm level, industry formation is understood from resources that are co-created at the level of a TIS (Musiolik et al. 2012; Musiolik and Markard 2011). TIS studies understand resources similar to relational economic geography as socially constructed entities that rely on collective processes of resource generation and application (Bathelt and Glückler 2005). Yet, its list of relevant resources differs from economic geography: EEG mainly emphasizes knowledge as the key resource (Tanner 2014). Relational economic geographers, in turn, distinguish between four resource types—material resources, knowl-

edge, power, and social capital (Bathelt and Glückler 2005). TIS literature, in turn, proposed six key resource formation processes, which we condense into four analytically distinct key resources here: knowledge, niche markets, technology legitimacy, and financial investment (see Table 1).

Economic geography and transition studies agree that knowledge lies at the heart of all path creation processes (Bergek et al. 2008b; Bathelt and Glückler 2005) and that knowledge creation and recombination is the decisive mechanism through which firms create and sustain their competitiveness (Bathelt and Glückler 2005). In our framework, knowledge is perceived of broadly as containing both explicit and tacit dimensions as well as experienced-based know-how and network-based know-who. Whereas some forms of knowledge are highly contextual and embedded in regional contexts, others are less sticky and easily transferrable in space. Early movers in a new field depend directly on creating and/or mobilizing this key resource.

Second, niche markets are considered a resource here since market segments for radically new technologies and products often do not preexist but have to be created by the actors themselves (Fligstein 2007; Dewald and Truffer 2011; Kemp, Schot, and Hoogma 1998). The early phase of the German solar photovoltaic (PV) industry might serve as an illustrative example: until the mid-1990s, a functional market for solar PV systems was missing globally. In the early 1990s, German technology experts, antinuclear activists, and communal policymakers formed strategic alliances that constructed a new market segment (private rooftop solar systems) and lobbied regional policymaking to adjust existing electricity grid regulations in favor of solar PV integration (Dewald and Truffer 2011). Once this market segment and related products were commoditized and a national feed-in tariff provided market support, the German PV path started booming. The German niche market consequently turned into a global resource that could get mobilized by new entrants to the industry in distant places (e.g., China) (Quitzow forthcoming).

Financial investment, in turn, is a key and often scarce resource for the actors in a new industrial field (Hekkert et al. 2007; Gustafsson et al. forthcoming). Especially in the very early industry formation phase, investment is often mobilized from various sources, containing angel investors, venture capital, as well as commercial and investment banks (Florida and Smith 1993; Corpataux, Crevoisier, and Theurillat 2009;

Table 1

Key Resources and Resource Formation Processes for Path Creation

Key Resource	Formation Process	Definition	Indicators
Knowledge	Knowledge creation	Activities that create new technological knowledge and related competencies (e.g., learning by searching, learning by doing; activities that lead to exchange of information among actors, learning by interacting, and learning by using in networks)	R&D projects, number of involved actors, number of workshops and conferences, activities of industry associations, linkages among key stakeholders, spatial dynamics in underlying knowledge networks
(Niche) markets	Market formation	Activities that contribute to the creation of protected space for the new technology, construction of new market segments	Number of niche markets, supportive tax regimes and regulations, subsidies
Financial investment	Investment mobilization	Activities related to the mobilization and allocation of basic financial inputs such as bank loans, venture capital or angel investment	Availability of financial capital and complementary assets for key actors, total sum of investment in companies in the field
Legitimacy	Technology legitimation	Activities that embed a new technology in existing institutional structures or adapt the institutional environment to the needs of the technology	Rise and growth of interest groups and their lobbying activities, institutional entrepreneurship by the actors in a new technological field

Source: Compiled and adapted from Bergek et al. (2008b), Hekkert et al. (2007), Musiolik and Markard (2011).

Pollard 2003). Since the commercial potential of the new products is uncertain, entrepreneurial actors will have to form stable alliances with investors and complementary actors to raise technology-specific expectations and secure sustained investment in the emerging path (Hekkert et al. 2007; Bergek, Jacobsson, and Sandén 2008). Often, relevant shares of investment are also raised from government organizations or intermediary actors (e.g., associations and interest groups), particularly to fund research and development (R&D) or demonstration projects (Hekkert et al. 2007; Bergek, Jacobsson, and Sandén 2008).

Legitimacy, finally, depends on aligning the new industry and its products with the relevant institutional contexts (Aldrich and Fiol 1994; Johnson, Dowd, and Ridgeway 2006; Binz et al. forthcoming). New products and processes that are not aligned with the regulative, normative, and cognitive institutions of a given place will be confronted with high skepticism and lacking user acceptance (Aldrich and Fiol 1994). To make the new industry and products appear desirable, early proponents have to engage in considerable institutional work to either adapt the innovation to existing institutional structures or adapt these structures to better match the innovation's needs (Bergek, Jacobsson, and Sandén 2008; Aldrich and Fiol 1994). Similar to the other resource formation processes, legitimation depends on interaction in heterogeneous actor networks and shows cumulative properties (Johnson, Dowd, and Ridgeway 2006): once an innovation is successfully validated in a local context, agents in another context will find it easier to diffuse the idea (e.g., through processes related to mimetic isomorphism) (DiMaggio and Powell 1983).

These four key resources can be understood as necessary conditions for industry emergence: if any of them are missing, the emerging industry will face a significant development barrier. Path creation, accordingly, depends on how these four resources emerge out of the systemic interplay between relevant actors, networks, and institutions, and the way they get aligned to each other (Suurs and Hekkert 2009). Measuring the resource formation processes and their alignment is challenging since in the very early path creation phase many of the key components (firms, networks, institutions, policy interventions) are still embryonic and loosely coupled (Bergek et al. 2008a). A range of qualitative indicators in Table 1 (derived mainly from TIS studies) is thus proposed to give rough measures of the intensity of these early alignment processes.

Anchoring Extraregional Resources in Early Path Creation

Whereas TIS studies, so far, mostly assessed how resources are mobilized from national or regional sources, recent work positions territorially agglomerated formation processes in the more or less densely connected networks of a wider global TIS (Coenen et al. 2012; Quitzow forthcoming; Binz, Truffer, and Coenen 2014; Binz et al. 2012; Dewald and Fromhold-Eisebith forthcoming). Similar to knowledge, other key resources do not necessarily emerge in densely localized settings only. They might as well develop in specific territorial subsystems and then get transplanted to a given region (Martin and Sunley 2006), or even develop in transnational companies or global communities in a completely internationalized way (Binz, Truffer, and Coenen 2014; Gosens, Lu, and Coenen 2015). In this perspective, anchoring is not a one-dimensional process of attracting external *anchor tenants*, which induce local knowledge spillovers (Feldman 2003), but an interactive process where regional actors mobilize knowledge, markets, legitimacy, and financial investment that emerge from formation processes in other regions of the global technological field. Over time, the extraregional resources will get connected to the actors, networks, and institutions that emerge in the region, and after some time, agglomeration economies and self-reinforcing processes lead to self-sustaining regional industrial development paths.

Assessing the performance of the resource formation and anchoring processes and their mutual alignment at different points in time can indicate if and how the key resources for industry formation are imported to or evolve in a given region. The more aligned these formation processes are in a region, the more resources get mobilized for local actors, and the stronger the anchoring of external resources and thus the better the conditions for the region to create a territorially distinct, path-dependent industrial path. In this approach, we are in line with De Propris and Crevoisier (2011, 172), who suggest that 'if regional growth is pursued through the anchoring of a new industry, this means transforming mobile factors into immobile factors to sustain a local process of firm agglomeration and knowledge accumulation.' Anchoring thus means coupling a region to extraregional resources and transforming them into locally sticky (Asheim and Isaksen 2002) resources through activities that can be described by the four key resource formation processes. This framework allows for a differentiated analysis for identifying failures in specific resource formation or alignment processes, which could, in turn, inform policymakers aiming at the support of regional path creation (Jacobsson and Bergek 2011; see Bergek et al. 2008b).

Case Selection and Method

The analytical framework laid out above will now be applied to assess the emergence of the OST industry in China, a case in point for a new industrial path-in-the-making whose spatial evolution challenges existing relatedness-based explanatory frameworks.

Overview of the OST Industry

OST has emerged over the last 20 years as a significant alternative to conventional, centralized wastewater treatment technology. It is based on small, flexible wastewater treatment plants that can be installed into single buildings and recycle wastewater on site. OST is considered a clean-tech industry with disruptive potential to the dominant development logic of the wastewater sector (Truffer et al. 2012): instead of relying on extended sewer networks and a centralized treatment system, it is based on small, washing machine-like treatment plants and decentralized operation and maintenance models. Whereas many of the basic technological components for OST plants are well developed, the relevant business models and operation and maintenance concepts are not (Truffer et al. 2012). To date, the technology has mostly been applied in rural low-tech markets, which are served by small-to-medium-sized companies that are widely distributed in space (Gebauer et al. 2012). Path creation in our empirical example thus means that OST is starting to be mass produced and applied in urban contexts, while inducing path-dependent industrial structures in specific regions.

OST represents an interesting case for our conceptual argument since innovation in this field is not only depending on R&D-intensive technological advancements but also on the development of new service and maintenance concepts, business models, as well as regulatory and institutional innovation. The case also promised interesting insights to the anchoring argument as OST technology is developing in a complex geographic actor structure: embryonic OST industries have developed in Japan, South Korea, the United States, as well as in Western Europe (Binz et al. 2012; Gebauer et al. 2012), and the industry's underlying knowledge network is strongly internationalized (Binz, Truffer, and Coenen 2014). The industry thus promised interesting insights into how interaction between different regions of the global technological opportunity set influences early path creation dynamics.

Case Study Sites

China was chosen as a focal area for this research for two main reasons: first, despite being a latecomer in the wastewater treatment field, it hosts some of the very few cities worldwide that have integrated OST systems in the urban core and developed its own emergent OST industry. Second, due to its very rapid development dynamics, China allows reconstructing path creation processes over a relative condensed time span (less than 20 years). This has strong methodological advantages for this article's qualitative research design: many of the actors in the field experienced the full local history of the industry and could give detailed accounts of how the OST path emerged. China obviously also provides a very particular cultural and institutional setting for industry emergence (Fligstein and Zhang 2011; Nahm and Steinfeld 2014; Witt 2014). Yet, in

Table 2

Initial Conditions of Three Chinese Cities, 1989

	Population[1] (Million Permanent Residents)	Related Industries[2] (Gross Output Value Million Yuan, Constant Prices)	Wastewater Treated (Million Tons)	Freshwater Resources per Capita (m3/person*a)[3]
Beijing	7.3	95	375	300[4]
Shanghai	8.2	319	930	1049[5]
Xi'an	2.8	93	126	350[6]

Sources: [1]University of Michigan China Data Center, http://chinadataonline.org/member/census1990/ybtableview.asp?ID=24.
[2]Instruments, meters and other measuring equipment (State Statistical Bureau of the People's Republic of China 1989).
[3]The Food and Agriculture Organization of the United Nations defines values below 1000 m^3/person*year as water stress, whereas numbers below 500 depict *absolute* or *acute* water scarcity.
[4]Zhang et al. (2007).
[5]Wang et al. (2008).
[6]http://www.china.org.cn/english/2004/Jul/100083.htm.

the present article we aim at illustrating the general utility of our analytical framework and thus refrain from an in-depth discussion of China's particular cultural context.

The cases for in-depth investigation inside China were selected based on purposive, theoretical sampling (Glaser and Strauss 1967), looking for both success and failure cases. Desk research showed that only Beijing hosts a considerable OST industry: six OST-related medium enterprises and one major international player in the OST field are located in this city region, which has more than 2000 OST systems installed in its urban core. Its (relative) success story was chosen for the most detailed investigation whereas Shanghai and Xi'an are discussed as contrasting cases (for a more detailed discussion, see Binz and Truffer forthcoming). The initial conditions differed considerably between the three regions (Table 2). Shanghai provided the most promising *generic resources*: when first OST experiments were undertaken in China, the city already had accumulated considerable experience with wastewater treatment technologies and had related industries in place. Beijing and Xi'an, in contrast, had less experience in the wastewater treatment field and provided considerably weaker related industrial capabilities, but were, in turn, confronted with more pressing water scarcity (Table 2; Jiang 2009). Beijing had an advantage in being the country's scientific hub with access to key related knowledge bases, whereas Xi'an hosted a particularly active entrepreneurial research group in a local university that was pushing OST from the early 1990s. In sum, none of the three regions (maybe except for Shanghai) had a clear initial advantage in developing an OST industry. Still, Beijing was the only region where an embryonic OST path emerged. In the remainder of this section, we will explore this observation based on our analytical framework.

Methods

Reconstructing the resource formation and alignment processes in early industry formation requires the researcher to focus on social construction and actors making sense of emerging situations. The most powerful tools to assess them in-depth are expert interviews and qualitative content analysis (Sydow et al. 2012; Yin 2009). In total, 40 interviews and five field visits to on-site treatment projects were conducted during an extended field stay in China between November 2010 and May 2011. Interviews covered relevant experts from all stakeholder groups involved in the

Table 3

Interviews in China

Stakeholder Group	Interviews Beijing (BJ)	Interviews Shanghai (SH)	Interviews Xi'an (XA)	Sum
Academia (AC)	Chinese Academy of Sciences (6), Qinghua, Beijing S&T University, Beijing Forestry University, Renmin University	Tongji University (2)	Xi'an University of Architecture and Technology	13
Domestic companies (DC)	Beijing Origin Water, Beijing Tooling, Beijing Hujia-Hanqing, Beijing Qingyuan	Shanghai 4F, Shanghai Zizheng, PACT Shanghai		7
Foreign companies (FC)	Siemens, Veolia, GE, Kubota, Hydranautics, Huber, Inge AG, DHV	Grundfos, Norit, ITT		11
Policy experts (PE)	Renmin University, Chinese Academy of Sciences (2)	China Construction Design Institute, Tongji University, Korea University	Xi'an Municipal Design Institute	7
Associations (AS)	International Water Association, Global Water Intelligence			2
Sum	27	11	2	40

process. Interview guidelines were structured according to the four key resources and alignment processes, and adapted to each stakeholder group. All interview recordings were transcribed verbatim, translated, and analyzed using qualitative content analysis (Glaser and Strauss 1967).

To increase construct validity and avoid post hoc rationalization, the interview data were triangulated with reports, Internet databases, publications, and company's annual reports in both English and Chinese. To guarantee anonymity, interviewees will be cited in the results section according to abbreviations in Table 3. For example, an academician from Beijing would be named ACBJ, a domestic company from Shanghai DCSH, a foreign company active in Shanghai FCSH, an association from Beijing ASBJ, and a policy expert from Xi'an PEXA. If several interviews covered the same expert group, the respective interviews were numbered (e.g., DCBJ1, DCBJ2).

Emergence of an OST Industry in Beijing

Table 4 summarizes the current state of Beijing's OST industry. Six companies dominate the field and Beijing Origin Water has developed into an international leader, exporting its systems to Australia, Eastern Europe, and Japan. In addition to these companies, about a dozen local research institutes are active in the OST field, and two key international intermediary organizations established representative offices in Beijing. Overall, the OST path in Beijing is still in an early development phase, but meets our definition of early path creation: the city arguably contains a set of functionally related firms and supportive actors and institutions that are established and legitimized beyond emergence and facing early stages of growth, developing new processes and products.

The history of this emerging industrial path started in the late 1980s, at a time when wastewater infrastructure was still largely missing in Beijing and most other parts of China (Browder et al. 2007; Fu, Chang, and Zhong 2008). Still, after a slow start, OST emerged in Beijing in a rather dynamic way and in three consecutive phases (Figure 1), which we will now assess in more detail.

Table 4

Key Companies in Beijing's OST Industry

Company Name	Founded	Number of Employees	Number of Plants Installed	Main Activity
Beijing Origin Water 北京碧水源科技股份有限公司	2001	1,625	>900	Membrane manufacturing, project design, system integration, installation, operation and maintenance (O&M)
Beijing Ecojoy 北京汉青天朗水处理科技有限公司	2002	30–50	>50	System integration, installation, O&M
Beijing Tooling 北京涛林环境工程有限公司	1999	30–50	>300	System integration, installation, O&M
EnviroSystems 万若环境	2003	25	>50	Project design, system integration, O&M
Beijing Wellhead 北京万侯环境技术开发有限公司	1995	51–100	>200	Project design, installation, O&M
Konckier Water 北京康基亚环境工程有限公司	2002	51–100	>100	Project design, system integration, installation
Others	Diverse	Diverse	>600	Diverse

Source: Triangulated data from interviews, company Web sites, reports and visits at trade fairs (note that although Beijing's OST industry has been growing rapidly, it is still not covered with official statistics, which complicates the creation of a comprehensive picture of all the activities in the field).

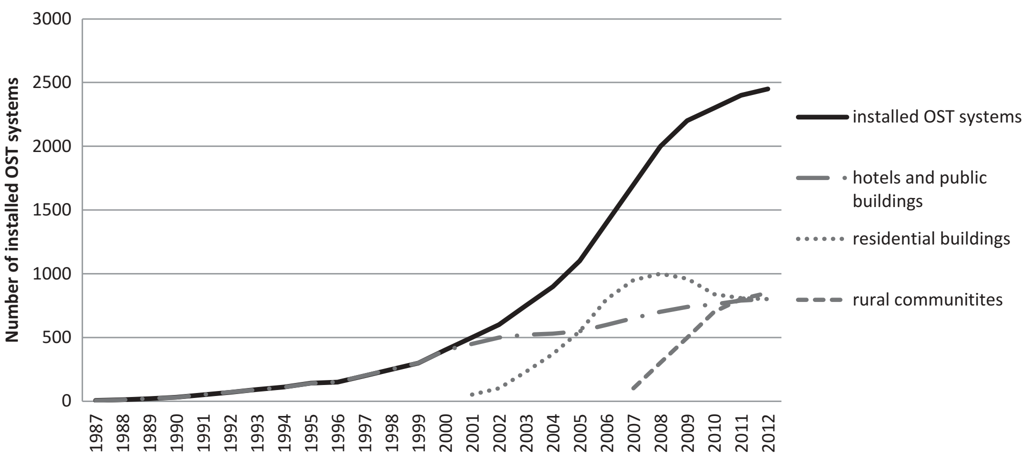

Figure 1. Number of installed OST systems in Beijing (cumulative).
Source: Estimates from interviewees.

Beijing 1990–2001: OST Gets Introduced in a Hotel Market Niche

The first OST-related activities in Beijing emerged in the late 1980s after a relatively small change in Beijing's water policy (DCBJ1, DCBJ3). In 1987, driven by increasingly pressing water scarcity, Beijing's local government formulated a new (provisional) regulation mandating hotels with a construction area exceeding 20,000 m^2 and public buildings with a construction area exceeding 30,000 m^2 to introduce OST facilities (Mels et al. 2006; DCBJ1, DCBJ2, DCBJ3). At the time, the indigenous technological know-how even for centralized wastewater treatment was still very limited, so in order to comply with this regulation, hotels had to refer to international companies (mainly from Japan, Germany, and France) for help with project planning and implementation (DCBJ2). At that time, innovation thus mainly happened in foreign companies that had experience with rural application of OST technology and developed new and improved technological solutions for the new market in large hotels. In addition, many large hotels in the city were run by international hotel chains, so not only was the first OST niche in Beijing served by foreign companies but also the initial investments and customers originated from outside the region (DCBJ2).

Key Resources and Alignment Processes

At this early stage, knowledge (state-of-the-art technology, O&M concepts, and qualified engineers) was mostly imported from elsewhere by introducing products of Japanese and European OST companies and engineers into the hotel niche (Binz et al. 2012). Initially, numerous foreign small and medium enterprises competed in Beijing's hotel market niche, but none of them could gain a dominant market share (DCBJ2). Only at the end of this first period did small Chinese engineering companies from the regional heating, steel piping, and water supply sectors start copying products of their international competitors and supplying very cheap but also largely dysfunctional products (DCBJ1). At this early stage, academic knowledge creation in Beijing was strongly dependent on dense interaction with OST research groups outside Beijing, mainly in Europe, Japan, and the United States (Binz, Truffer, and Coenen 2014; ACBJ1): A research group from Qinghua University got included in the global research network of a transnational water company and developed quickly into a globally leading group in membrane bioreactor technology, a core process for OST systems (Binz, Truffer, and Coenen 2014; ACBJ1). Still, the local universities and research institutes started experiments with their first local OST pilot plants only in the late 1990s (ACBJ3, ACBJ2) and their activities were rather explorative, aimed at scientific discoveries and not yet connected to local industrial partners (ACBJ4, ACBJ3).

Legitimacy of OST was not highly contested since there was general agreement on the need of new water-saving technologies for this very water-scarce city (ACBJ5). Also, although OST was in conflict with several regulative institutions in the city's residential water sector governance, the hotel niche was a special case with its own particular selection environment. Legitimacy was also created in other regions around the world where OST got locally validated in rural application niches. The positive experience with international systems in large hotels helped later diffusion of the technology: thanks to international management, professional operation, and economic profitability of OST systems in large hotels, local engineers and practitioners first realized the full potential of the idea (DCBJ2) and local universities started taking up OST as a field of study (ACBJ2, ACBJ1). Finally, since the hotel market in Beijing was strongly driven by extraregional networks, *investment* was mainly *mobilized* through the presence of foreign actors and the investment decisions by international hotel chains.

In sum, the only key resource formation process that can be attributed to a regional scale in Beijing in the first phase is *niche market formation*: by introducing the hotel regulation, Beijing's government created a protected space for technology experimentation that made local actors start to perceive the OST systems' market potential, commodify first products, and develop experimental pilot plants. At the end of the 1990s, OST in Beijing was a regulation-driven market niche, which was strongly coupled with key resources developing outside China. Still, the legitimacy, knowledge, niche markets, and investment induced at that time proved to be decisive for later path creation phases.

2001–2007: Entrepreneurial Experimentation in Residential Buildings

At the beginning of the new millennium and based on the positive experiences from the hotel market, Beijing's government decided to extend its OST regulation to residential development areas (DCBJ1, ACBJ2). Starting from 2003, new residential construction projects exceeding a total floor surface of 50,000 m^2 were forced to install OST facilities (Mels et al. 2006; DCBJ1 4, DCBJ4, DCBJ5). Since real estate construction was booming at the time, this legislation meant that most new residential projects in Beijing had to include on-site systems (ACBJ2).

Key Resources and Alignment Processes

First and foremost, this extension of existing regulation to residential buildings opened an additional and considerably large market where local and external actors could further experiment and commoditize their OST products. Apart from this most direct effect, the new market niche also led to a surge in the other resource formation and alignment processes. Considerable financial investment got mobilized for the local industry; since the real estate developers were basically forced to integrate OST systems into their new projects, they installed locally sourced OST systems (DCBJ1) and spread the additional costs to the tenants through higher apartment rents (FCBJ1).

As the demand and available investment for on-site systems skyrocketed, new companies got founded that started *creating* new *knowledge*. All of our interviewed companies were established around the year 2000, either as spin-offs from local universities (DCBJ5, DCBJ6) or by entrepreneurs returning from Europe, Japan, or Australia (DCBJ4, DCBJ3, DCBJ6). According to the interviewees from local companies, their main motivation to found companies was not connected to the available *generic resources* in Beijing but to a sense of opportunity in mobilizing their foreign specialized technological knowledge and anchoring it in a unique learning environment in their (institutionally and socially proximate) hometown. In the first few years, these entrepreneurs took advantage of Beijing's enabling environment by engaging in *learning by doing* (DCBJ3, DCBJ1): they developed new technological OST concepts, installed them in residential buildings, and then learned on the spot about the technological and organizational challenges (DCBJ1)[2]. In this process, local actors increasingly took over the hotel market segment from international companies that started pulling out of the strongly competitive market (DCBJ1). Together with learning by doing in the industry, knowledge creation also got aligned with local universities (ACBJ1). Many research institutes started cooperating with local companies either because some of their graduates launched their own companies (DCBJ5) or because start-ups needed scientific expertise in the configuration and early operation of their OST plants (DCBJ4). Knowledge creation now happened in increasingly distributed

[2] A process similar to what Garud and Karnøe (2003) called bricolage.

local networks, especially with start-ups and research organizations involved in intensive reciprocal learning. Since much of academia was at the same time strongly linked internationally, this setup facilitated the constant translation of international best practices into Beijing's emerging OST industry (ACBJ1).

Finally, despite the emergence of an increasingly vibrant innovation system in the OST field, Beijing's emerging path later ran into a serious *legitimacy* crisis: after about five years, the market segment in residential buildings turned into a failure, mainly due to inconsistencies between the technology's needs and the institutional context in this specific market segment (DCBJ1, DCBJ3, DCBJ5, ACBJ2, ACBJ3). In residential buildings, professional operation and maintenance of OST plants could not be guaranteed, and the price structure in Beijing's water sector was such that residential OST plants could not be operated profitably (Li et al. 2013; ASBJ1, ACBJ5). According to our interviewees, only about 10–20 percent of the systems initially installed in residential districts are still fully operational today (DCBJ1, ACBJ2, DCBJ3). This failure eroded trust from residential end users and experts, and strongly delegitimized OST in Beijing. Even though by the mid-2000s the local industry had built up basic technological and organizational know-how, the dire institutional context in the residential market made OST increasingly look like an undesirable solution (ACBJ6). Had there not been the still successful hotel market niche and a quickly growing local industry, the OST path would probably have ended in complete delegitimization at this point in time (DCBJ4).

In sum, in the second phase, several resource formation processes got more aligned, and extraregional knowledge that had entered the region in the first phase got increasingly anchored locally in a dynamic entrepreneurial experimentation process. One crucial anchoring process in that time was triggered by returning highly skilled experts, which saw an opportunity in using their externally acquired know-how to establish companies in a globally quite unique environment that supported experimentation and interactive learning. Linkages to other important regions in the global field of technology also remained crucial, especially through the internationally well-connected regional science system.

2007–2012: Industry Consolidation and Intensified Resource Alignment

Despite the fiasco in the residential market, Beijing's OST path continued developing in a third phase, and the industry got embedded in an increasingly vibrant OST-related innovation system: industry–science interaction further intensified, specialized OST research groups were established, and international advocacy coalitions for OST systems located in the city (ACBJ8). The biggest industrial player, Origin Water, started to manufacture a mass-produced standardized treatment plant that became a template for other OST firms inside and outside Beijing (DCBJ5). The company developed into a global leader in water recycling technology and is now a direct competitor to major international players like GE, Siemens, or Kubota. The actor base stabilized and interpersonal *guanxi*[3] ties between industry, academia, and the local authorities got denser (DCBJ1)[4]. Concomitantly, the experience of Beijing started radiating to other places, and advocacy coalitions for rural OST systems developed increasing visibility throughout China (ACBJ7, ACBJ8).

[3] Interpersonal ties, based on reciprocity, a very important structural element of Chinese society (see, e.g., Xin and Pearce 1996).

[4] In the Chinese context, this is a clear indication that the emerging path has matured to some degree.

Key Resources and Alignment Processes

Knowledge creation further intensified in this last phase, both inside and beyond Beijing's immediate context: with an increasing national push for infrastructure build-up in rural areas, a research institute of the Chinese Academy of Science in Beijing applied for national funding for a competence center for rural OST systems. The center was approved and is now running large-scale field studies that try to find suitable technologies and maintenance schemes for OST systems (ACBJ7, ACBJ8). Some successful experiments got published as cover stories in highly prestigious national technology magazines (ACBJ8). Also, international advocacy coalitions for OST systems started knowledge dissemination and lobbying activities, mainly through highly devoted academics and entrepreneurs (ACBJ2, DCBJ3). The International Water Association organized high-profile conferences on OST systems in Xi'an and Harbin,[5] further linking scientist in the field both inside China and with different experts from other key subsystems of the global technological opportunity set (ASBJ2).

The small but well-connected advocacy coalition in Beijing's OST industry could also successfully lobby the local government to further expand *market formation* to the rural fringe of Beijing (DCBJ1). A group of technology advocates around the regional industry champion, Origin Water, convinced Beijing's government to start installing OST systems in environmentally sensitive suburban areas around the city (DCBJ4). Learning from the failures in the residential market, new technological solutions and a comprehensive operation and maintenance system were developed with engineers permanently repairing distributed systems. At the same time, OST markets increasingly developed in other regions of China, especially in southern rich rural areas and in water-scarce cities in northern and western China (ACBJ8, DCSH1, DCSH2). Most companies in Beijing accordingly diversified into suburban, rural, or industrial markets (DCBJ5, DCBJ1). In addition, Japanese OST companies entered China again, this time targeting the emerging suburban and rural market segments (FCBJ2). OST systems still had to be installed in hotels and new residential developments (ACBJ2, PEBJ1), but these two market segments now slowed down (DCBJ3, FCBJ2, DCBJ5).

In terms of *investment mobilization*, new pools for funding got available from two main sources. First, several national and regional R&D programs allocated funding to OST projects in Beijing's universities and research institutes, and new subsidy schemes for rural OST systems were developed in various southern provinces. Second, in April 2010, the initial public offering of Beijing Origin Water at the Shenzhen Stock Exchange mobilized an additional extraregional source of investment for the further development of OST technology in Beijing[6]. Similarly, in the last phase, several actors of the Beijing OST industry developed a coordinated lobbying strategy, which helped them save OST's damaged *legitimacy* (DCBJ4, DCBJ3). All of the interviewed company managers claimed that they invested heavily in making presentations at conferences and symposia in order to educate key stakeholders about the benefits of OST systems in residential and nonresidential markets and to further stabilize basic government support and technology legitimacy with end users and experts (DCBJ3, DCBJ5, DCBJ4, DCBJ1).

In sum, after a complex resource formation, anchoring, and alignment process, lasting about 20 years, the small OST industry in Beijing started providing regionally

[5] Cities of the Future Xi'an: Technologies for Integrated Urban Water Management (Xi'an 2011); 11th IWA Conference on Small Water & Wastewater Systems and Sludge Management (Harbin 2013).

[6] By 2015, Origin Water had a market capitalization of more than US$5 billion.

confined spillover effects to its local actor base that EEG would recognize as a new regional path: the local science system produces a steady flow of specialized engineers for the local industry; Beijing's companies export their systems throughout China and internationally, and reinvest their revenues into the build-up of large cutting-edge production facilities in the city's suburbs[7]. Also, interactive learning between local industry, city planners, and academia has created an OST-related innovation system that increasingly attracts outside experts to study the city's OST experience,[8] thereby further extending the regional knowledge base. Even though the future development of OST is hard to predict, Beijing mobilized and anchored the key resources to further develop its local path in this emerging industry.

Discussion

Table 5 further summarizes the resource formation processes in Beijing's OST industry in the three observed development phases. Resource formation changed from extraregionally dominated to a regionally anchored setup: whereas most of the key resources were imported from outside the city in a first phase, they were gradually transformed to endogenous regional resources in later development stages. In a nutshell, Beijing's success in creating an OST path lies in a three-step anchoring process: first, regional actors mobilized experts and access to resources from other places through opening a small market niche to foreign companies. The basic knowledge, investment, and legitimacy mobilized in this small market niche motivated highly skilled returnee entrepreneurs to found de novo start-ups and local actors to start spin-offs from related sectors and local universities. Second, the imported cutting-edge know-how increasingly transformed local market, investment, and knowledge structures in a localized learning-by-doing process. Finally, most resource formation processes were retained and aligned in a regional, yet internationally well-connected innovation system forming around OST technologies. Beijing's path in OST technology emerged from the interplay among industrial, academic, and governmental actor groups, which drew on both local and extraregional sources to mobilize and align the knowledge, markets, investment, and legitimacy needed for industry formation. Interestingly, this process was not intended or planned from the outset but emerged out of the local and extraregional alignment dynamics driven by distributed actor networks in Beijing's context.

Applying the same analytical perspective to Shanghai and Xi'an (for a more comprehensive discussion, see Binz and Truffer forthcoming) reveals that the different resources for industry formation were not aligned in an equally balanced way. The actor networks in these regions did either not mobilize key regional resources or failed to anchor them from extraregional sources. Shanghai at the outset had strong technological relatedness and connections to key global water technology companies in place, but no notable OST path emerged. Rather, the regional actors relied on investments from international donor agencies and a large transnational water company to build up an extensive conventional centralized wastewater infrastructure (Lee 2006). The city's water industry accordingly got locked in to producing components for large-scale centralized wastewater treatment plants. Missing knowledge creation and market formation additionally hindered Shanghai from developing an OST path: the city's

[7] See http://www.originwater.com.

[8] For example an EU-funded, global research project (SWITCH) devoted a whole chapter to studying and improving Beijing's OST systems. http://www.switchurbanwater.eu/cities/3.php, accessed 21 October 2014.

Table 5

Summary of the Performance of Key Anchoring Processes in Beijing

		Knowledge Creation	Market Formation	Creation of Legitimacy	Investment Mobilization
Hotels 87-00	Extraregional	++ Knowledge imported to Beijing by foreign OST companies		+++ Positive experience with imported hotel systems legitimizing OST	++ Initial investment provided by international hotel chains
	Regional	+ Learning in the hotel niche and first research in Beijing's science system	++ Beijing's city government creating a protected market niche in hotels		
Residential 00-07	Extraregional	+++ External knowledge imported through academia, companies and returning experts		++ Returnee entrepreneurs lobbying for and promoting OST	
	Regional	++ Tight industry-university linkages, spin-offs from local research institutes	+++ Beijing's city government extending OST regulation to residential projects	– Massive failures in the residential market	++ Local real estate developers paying investment costs for OST plants
Rural 07-12	Extraregional	+ External knowledge imported through international organizations, academia	+ Beijing industry serving markets in other regions of the global TIS		+ Beijing Origin getting listed at Shenzhen stock exchange, raising international investment
	Regional	+++ University-industry linkages, specialized research groups, associations emerging in Beijing	+++ Beijing actors lobbying for and constructing a new market niche in rural areas	++ Company managers and system intermediaries holding presentations, educating key stakeholders on OST	++ Local companies mobilizing investments from local government and real estate developers

Notes: + weak; ++ average; +++ strong hindering.

universities did for a long time not develop curricula in OST technologies, and there was no regulation-driven market niche as well as no experience in related market segments like district heating (which was readily available in Beijing).

In Xi'an, in turn, knowledge creation was strongly pushed by an entrepreneurial returnee professor, but other key resource formation and anchoring processes were missing: his research group at Xi'an University of Architecture and Technology induced several large research projects on OST and convinced the local government to plan and fund local pilot projects (Wang et al. 2008). These projects were broadly considered a success and created legitimacy for OST beyond the regional borders. Still, Xi'an's path formation process remained strongly centered on this single key actor and never initiated distributed learning, market formation, investment mobilization, or a wave of start-ups like in Beijing. This single anchor tenant was unable to mobilize and align all the key resources for successful industry formation. The comparison with Beijing reveals that especially demand-side effects and the succession of a set of differing market segments might have been a crucial missing factor in Xi'an.

Three main insights stand out from these results. First, our evidence shows that the path creation process depended equally on regional and extraregional key resources: one part of Beijing's success is explained by the fact that it was able to attract foreign technology, investment, companies, and later knowledgeable experts and entrepreneurs. Another part is then attributable to the fact that it was able to retain these elements and continuously mobilize them regionally. In contrast to the original concept by Crevoisier and Jeannerat (2009), the observed anchoring process did, however, not only refer to knowledge but also to the mobilization and alignment of other key resources like market access, technology legitimacy, and investment. Second, system-building dynamics on the demand side (the succession of a set of differing, yet related market segments, as well as preexisting competence in operating and maintaining related technologies like heating and boiler systems) was a crucial success factor in Beijing.[9] This finding supports recent claims that evolutionary theories would have to be adapted to include demand-side relatedness more strongly in their path creation concept (Tanner 2014; Gilbert and Campbell 2015).

Third and finally, our results confirm that government interventions are to be seen as a key ingredient (but far from determinant) for industrial path creation (in line with recent findings from Dawley 2014). In the OST case, the local government interventions played an important role especially in fostering the protected niche markets where other resource formation and alignment processes could take shape. Especially in the Chinese context, local and central governments are often assumed to play a key role in supporting new industrial paths (Nahm and Steinfeld 2014; see, e.g., Gallagher 2014). In the present case, however, government actors were not steering the development process with rigid, top-down industrial policies, but were rather experimenting with tentative policies and reacting to industry scale-up and emerging advocacy coalition's lobbying efforts. Even in China's centralized governance system, government actors alone could not induce the complex distributed agency and all resources needed for industry formation.

Conclusions

This article set out to develop an analytical framework for path creation that explicitly unpacks the generic resources and early resource formation processes that drive the emergence of new industrial paths. We argued that EEG's emphasis on endogenous branching processes from (pre-)existing industries and firm-based organizational routines in the region are downplaying the role of nonfirm actors, institutions, policy intervention, as well as nonlocal linkages. The presented analytical framework broadens existing knowledge-centric accounts with additional explanatory dimensions (markets, investment, and legitimacy) and adds a new perspective on how these resources get mobilized, aligned, and anchored in the early path creation phase. In our view, industrial path creation in a region is not only depending on the degree of technological relatedness that is in place at the outset but also to the distributed agency in the very early industry

[9] This result is in line with earlier work on market formation in a TIS context that proved the importance of different market segments for building up a PV industry in Germany (Dewald and Truffer 2011).

formation phase, for example, the way early actors mobilize and anchor key resources for industry formation both from inside and outside the region.

Instead of relying on knowledge dynamics as the key generic resource, we used recent insights from transition and innovation studies to further specify and distinguish between four resources. Disentangling the actor networks and institutional contexts of knowledge creation, market formation, legitimation, and the mobilization of financial investment helps extending the explanatory variables of path creation concepts beyond firm-based organizational routines and knowledge dynamics. Since EEG, TIS, and transitions literature share the same roots in evolutionary economics, our framework further builds constructive bridges between the—as MacKinnon et al. (2009) rightfully state—often unnecessarily divided streams of evolutionary, institutional, and relational economic geography. Although technological relatedness and firm routine diversification play a key role in our framework, they are also put into the broader perspective of a more distributed innovation process in the relevant institutional, market, and finance contexts. Each of the identified four key resources can be expected to evolve in their specific path- and place-dependent trajectories, similar to what has been broadly assessed for the knowledge dimension. Future work could set out to analyze these resource formation processes in more detail and develop new hypotheses on the specific forms of relatedness that influence their spatial evolution.

Second, we specified the spatial origin of generic resources in more detail by relying on the anchoring concept. Knowledge, niche markets, investment, or even legitimacy do not necessarily have to get mobilized from inside the region. They might as well develop in actor networks outside the region and then be anchored to the regional path creation process through the activities of transnational entrepreneurs, international donor organizations, global investment banks, multinational corporations, or traveling technocrats. Further analysis of how this anchoring of extraregional resources works would be of particular importance to create more nuanced explanations of why new paths emerge or get *transplanted from elsewhere* (Sunley 2008) to specific regions although they fail to develop in other regions with similar or even better technological relatedness and generic resources in place (Dawley 2014).

In summary, we thus maintain that the presented framework helps develop more nuanced answer to the fundamental questions how and where new industries emerge and if they need the local presence of related industries (Boschma and Martin 2010). Based on our framework and case study, we argue that new industries depend on coevolving territorial and sociotechnical embedded innovation processes and—arguably increasingly important—linkages to other regions in the global innovation system forming around a new technology. This article and other recent empirical cases (Tanner 2014; Quitzow forthcoming; Gosens and Lu 2013) show that technological (and other forms of) relatedness are key necessary conditions for industry formation (Boschma and Frenken 2011a), but to understand how and where these preexisting resources induce structural change, one has to include a broader view on system formation, resource alignment, and anchoring of extraregional resources.

It goes without saying that the findings presented above leave space for further improvements. First, our single case study design limits the direct generalizability of our results. OST technology was chosen as an extreme case that illustrates the innovation challenges in an infrastructure sector that relies on synthetic knowledge bases and interactive learning by doing. As such, the observed patterns might be most informative for similar industries, for example, in other infrastructure-related emerging clean-tech fields like wind power, biofuels, or electric mobility. Future studies would have to assess how they differ in emerging industries with analytic or symbolic knowledge bases. In addition, China provides a quite unique institutional context for path creation processes, which we could not explore in much detail here. Our results are thus to be understood as mostly analytically generalizable, meaning that the developed framework could (and should) be applied to emerging sectors in different sectorial and regional contexts to further validate it and expand its explanatory power (Dawley 2014; Tanner 2014).

Second, we only had limited space to discuss each key resource for industry formation in much detail here. Future work should use literature from related fields of the social sciences to further specify each resource and disentangle their relevant subdimensions. For example, legitimation could be further specified by relating to institutional sociology literature, and the key dimensions of investment mobilization could be reframed based on recent insights from business literature or more critical political ecology perspectives. Also, power and social capital were not explicitly included in our list of resources. Whereas a thorough discussion of power was beyond the scope of this article, we do not deny the possibility that this important dimension could be included in the proposed framework. Social capital was implicitly conceptualized as an emergent outcome of the increasing interaction in an emerging TIS; since new actor networks emerge and engage in knowledge creation, market formation, investment mobilization, and technology legitimation, the social capital available to the actors in the systems was expected to grow. Future work could conceptualize this important process in more detail.

Finally, our results show that transnational entrepreneurs appear to be in a unique structural position to perceive development potentials that are invisible to purely regionally embedded actors. Although we could not explore this topic in much depth here, this finding resonates with insights in cluster studies (Saxenian 2007; Giuliani and Rabellotti 2012; Yeung 2009) and could be further scrutinized in related research.

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