Article:
Huang, P. orcid.org/0000-0002-7573-715X (2019) The verticality of policy mixes for sustainability transitions: A case study of solar water heating in China. Research Policy, 48 (10). 103758. ISSN 0048-7333

https://doi.org/10.1016/j.respol.2019.02.009

The verticality of policy mixes for sustainability transitions: A case study in China

Abstract: Climate change and sustainable development are the defining challenges of the modern era. The field of sustainability transitions seeks systematic solutions for fundamental transformations of socio-technical systems towards sustainability, and exploring the role of policy mixes has been a central research agenda within the field. In the extant literature, there exists a lack of both conceptual and empirical research on the vertical dimension of policy mixes for sustainability transitions. This study provides a multilevel and evolutionary interpretation of the vertical interactions of policy mixes in the process of industrial path development towards sustainability transitions. An exemplary case of solar water heating (SWH) technology in Shandong Province in China is presented, capturing both the bottom-up and top-down processes of interactions. On the one hand, urban-level policy initiatives can inform higher-level policymaking; on the other hand, national-level priorities can greatly configure policy strategies for lower-level governments. Moreover, as the industry matures, the interactions of multilevel policy mixes evolve from simpler, unidirectional patterns to more complex, bidirectional ones through a vertical policy-learning feedback mechanism. This study generates two important policy implications that extend beyond the Chinese context: first, dynamic vertical interactions between multilevel governments indicate the need to develop more nuanced perspectives on the design of policy mixes; second, policy makers need to hold a more dynamic view of policy mixes by recognizing their temporal and coevolutionary nature through the policy learning process.

Keywords: multilevel policy mix; verticality; resource anchoring; coevolution; sustainability transitions; China

1. Introduction

Climate change and sustainable development are the defining challenges of the modern era. The disastrous consequences of global warming, such as rising sea levels and extreme weather, occur more frequently, posing significant risks to natural and human systems (UNFCCC, 2017). Meanwhile, the long history of unsustainable economic growth has caused many social and environmental problems, with an intensification of social inequality, resource scarcity and ecological vulnerability. Echoing the dual challenges of addressing climate change and enabling sustainable development, the field of sustainability transitions attempts to capture the dynamics that induce long-term, multi-dimensional, and fundamental transformations of socio-technical systems towards more sustainable configurations (Smith et al., 2005; Markard et al., 2012). Exploring the role played by policy processes in sustainability transitions is a key research challenge faced by transition scholars (Markard et al., 2012; Edmondson et al., this issue). The emerging cases of the failures of markets, systems, and institutions during the process of sustainability transitions indicate that transition policies with simple and unitary policy instruments are no longer sufficient (Lehmann, 2010); instead, more systemic arrangements with the coordination of multilevel, multifaceted policies are necessary (Weber and Rohracher, 2012). A policy mix thus emerges as a more comprehensive approach to the design of transition policies (Reichardt et al., 2016; Reichardt and Rogge, 2016).

A policy mix comprises dimensions of both verticality and horizontality (Del Rio, 2014; Magro and Wilson, this issue). In the extant literature, the focus of analysis has mainly been on the horizontal dimension of policy mixes, such as the interactions between policy instruments at the same governance level (Strambo et al., 2015). Recent years have seen increasing interest in the vertical dimension of policy mixes for sustainability transitions (Flanagan et al., 2011; Lanahan and Feldman, 2015) in response to the changing situation in which, on the one hand, subnational governments exhibit increasing autonomy in the policymaking and implementation of a transition and, on the other hand, urban and regional policy networks exert an increasing impact on the effect of the distribution and transmission of national priorities and targets (Truffer et al., 2010). However, there remains a lack of both conceptual and empirical research on the vertical dimension of policy mixes for sustainability transitions. In particular, it remains unclear how multilevel policy mixes operate in real-world implementation and through which interactive mechanisms. More importantly, the verticality of policy mixes is seldom interpreted from an evolutionary perspective. This

perspective is important because policy mixes coevolve with the socio-technical system. Previous studies have provided mounting evidence on the temporal interdependencies between policy mixes and sustainability transitions (see, for instance, Reichardt et al., 2016; Edmondson et al., this issue).

In light of this background, this study provides a multilevel and evolutionary interpretation of *the vertical interactions of multilevel policy mixes during the industrial path development towards sustainability transitions in a region*. The field of sustainability transitions has extensively documented the incubation of technological innovation and the formation of more sustainable industries within a region, which eventually facilitate fundamental transformations of the regional socio-technical system (Essletzbichler, 2012; Gibbs and O'neill, 2014; Yu and Gibbs, 2018a). Essletzbichler (2012), for instance, discusses the formation of the wind power cluster in Navarra, Spain, and how the industry facilitates energy transitions in the region. Therefore, the path creation and development of (more sustainable) industries in a region offers a useful lens through which to explore the evolution of a regional innovation system towards sustainability transitions. The main contribution of this study lies in the differentiation of policy mixes at multiple spatial scales (national, regional, and urban levels) and the uncovering of their dynamic interactions in shaping regional industrial path development towards sustainability transitions.

Through the case of the solar water heating (SWH) industry in Shandong Province in China, this study provides an empirical illustration of the vertical complications of policy mixes. The findings capture both the bottom-up and top-down processes of interactions, with the urban government and the central government playing more active roles than the provincial government. The results also show that as the industry grows and matures, the interactions of multilevel policy mixes evolve from simpler patterns to more complex and adaptive ones. This research contributes to the conceptualization of policy mixes for sustainability transitions by highlighting the verticality of policy mixes, accounting for which configurations will facilitate a more nuanced design of policy mixes. It also provides a rationale for an evolutionary perspective on policy mixes. Recognizing the transient nature of policy mixes is conducive to the design of more open-ended and reflexive innovation policies.

The remainder of this article proceeds as follows. The following section delineates the main concepts and the analytical framework applied in this study. Section 3 introduces the study area, research data and methodology. Section 4 presents the empirical study of the SWH industry in Shandong Province in China, where the vertical interactions of multilevel policy mixes are uncovered. Conclusions and policy implications are drawn in Section 5.

2. Concepts and analytical framework

2.1. Policy mixes for sustainability transitions: a multilevel and evolutionary interpretation

Sustainability transitions entail fundamental and radical transformations of current socio-technical systems towards those that are more sustainable and environmentally friendly (Markard et al., 2012). The ‘policy mixes’ approach offers a more comprehensive perspective of transition policies (Reichardt et al., 2016; Reichardt and Rogge, 2016). Recent years have seen a substantial conceptual development of policy mixes for sustainability transitions.

A multidimensional policy mix consists of elements, processes, and characteristics (Rogge and Reichardt, 2016). This study focuses on the elements and processes of policy mixes. The elements refer to a policy strategy and an instrument mix. The policy strategy is often designed with long-term objectives and principal plans, in which quantitative long-term targets are usually set for targeted sectors. The instrument mix consists of core instruments and the surrounding complementary instruments (Schmidt et al., 2012). For instance, in Germany’s *Energiewende* strategy, the core instrument is the ‘Renewable Energy Sources Act’, which is complemented by a series of other instruments. The policy mix elements are generated and shaped by the policy processes of policymaking and policy implementation (Richardson, 1982). In the context of sustainability

transitions, both policymaking and policy implementation are highly politically oriented, involving adaptation and learning on the one hand and resistance to change on the other (Kern and Howlett, 2009; Flanagan et al., 2010).

Flanagan et al. (2011) conceptualized the dimensions in which policy mix interactions can occur, where the 'governance space' dimension denotes the interactions across different levels of governance. This dimension recognizes the inherent multilevel character of policy mixes (Flanagan et al., 2010). As observed by Bressers and O'toole (2005), multilevel governance is a key feature of the 'networked complexity' of policy mixes, particularly for policy mixes that aim to foster innovation and sustainability transitions within a region, as policy strategies and instruments at the regional level are not isolated but rather interact closely with the priorities of both the national and urban governments (Smith, 2007; Dawley, 2014; Dawley et al., 2015). Accounting for multilevel interactions is important for innovation policymaking in that the confluence of instruments enacted by different levels of government might reinforce or weaken the effects of policy implementation and thus complicate the outcomes of policy mixes (Bressers and O'toole, 2005). Recent years have seen growing recognition of the significance of the vertical dimension of policy mixes (Flanagan et al., 2011; Lanahan and Feldman, 2015). Empirical evidence shows that there often exists overlaps and incoherence between multilevel policy mixes (Flanagan et al., 2011), and a lack of coordination between local initiatives and central governments can eventually jeopardize the implementation outcomes (Howlett et al., 2017). Nevertheless, we still lack an adequate understanding of the mechanisms of interactions within multilevel governance systems.

More importantly, the multilevel nature of policy mixes is rarely examined together with the evolutionary process of an innovation system. There has been a tendency to adopt a static view, looking at the interactions exclusively within the political decision-making system, and examining the stances of and responses among different levels of governmental authorities, while the impacts and feedback from broader socio-technical dynamics outside the political arena are often neglected (see, for instance, Lanahan and Feldman, 2015). This study argues that applying an evolutionary perspective to analyse multilevel policy interactions is both important and necessary because innovation policy mixes coevolve with the socio-technical system affected by them (Reichardt et al., 2016). In reality, policy mixes often need to adapt along with the changing stages of innovation and transitions (Turnheim et al., 2015). A very recent study, for instance, showed how policy mixes influence socio-technical change and, in turn, how developments to the socio-technical system further induce adaptations of policy mixes through a range of feedback mechanisms (Edmondson et al., this issue). In light of this, the study argues that the interactions between multilevel policy mixes can be revealed only within the co-dynamics of policymaking and the innovation system.

In an effort to bridge the above research gap, this study places a central focus on the multilevel nature of policy mixes through the differentiation of policy elements and processes at multiple levels of governance (the national, regional, and urban levels) and examines their interactive dynamics unfolding in the coevolutionary process of policy mixes and the regional innovation system.

2.2. Industrial path development through the anchoring of key resources

The formation of more sustainable industries in a region induced by technological innovation can provide meaningful pathways for sustainability transitions (Essletzbichler, 2012; Gibbs and O'neill, 2014; Yu and Gibbs, 2018a). The process of industrial path development in this study is observed through the lens of resource flows, which are considered imperative for shaping supportive structures for fundamental changes in innovation systems (Hekkert et al., 2007; Bergek et al., 2008; Tanner, 2014). Following this line of thought, the concept of 'anchoring' is of particular relevance. In economic geography, Feldman (2003) first used the concept of 'a regional anchor' to explain the formation of a clustered industry in one region and the development of regional specialization, which is defined as a catalyst that creates a flow of ideas and enables knowledge externalities. In Feldman's definition, as noted by De Propris and Crevoisier (2011), the process of anchoring means

"attracting, harbouring or pegging a resource that could otherwise move elsewhere" (p. 6). Against the backdrop of globalization, resources (knowledge, labour, capital, etc.) are moving increasingly more freely across space. Resources can no longer remain static in one location but must interact with elements outside the location to maintain innovation levels (De Propris and Crevoisier, 2011). Moving beyond the clustering of a sector within a rather isolated regional innovation system, regions are increasingly engaging in multilocation networks of knowledge and resource specialization. Responding to the challenges of a more mobile world, Crevoisier and Jeannerat (2009) propose a further conceptual development and add another dimension (mobility) to the concept of 'anchoring'. Under this conceptualization, anchoring is no longer a one-dimensional process of attracting external anchors (Feldman, 2003) but rather an interactive process of mobilizing resources and recontextualizing them within a region (Crevoisier and Jeannerat, 2009; Vale and Carvalho, 2013; Binz et al., 2016).

In the literature, the application of the 'anchoring' concept is confined mainly to the resource of knowledge (Crevoisier and Jeannerat, 2009; Vale and Carvalho, 2013). Knowledge is considered a key factor in innovation and industrial path creation and has been given particular attention in economic geography and in innovation studies (Isaksen and Trippl, 2016; Asheim and Gertler, 2005). Recently, Binz et al. (2016) extended the application of anchoring to other types of resources. Based on the technological innovation system (TIS) framework, Binz et al. (2016) conceptualize four key resources for the industrial path creation process: knowledge, financial investment, legitimacy, and niche markets. In addition to knowledge (technology) and financial resources, which are widely recognized as general resources for industry development, legitimacy is also considered an intangible resource. Its formation contributes to the validation of an innovation in local contexts, such as place-based regulations, institutions, and social and cultural norms (Bergek et al., 2008; Binz et al., 2016). Binz et al. (2016) define the resources of niche markets as a protected space for the new technology. Here, the market is viewed as a resource because the authors look at early-stage industrial path creation in which access to new market segments constitutes an intangible asset possessed by transition actors and exemplifies their transition capabilities. However, as the new industry develops in the region, the market grows from niche markets to more mature markets, and gradually, it is viewed more as an outcome of the transitional process and an important indicator for sustainability transitions (Hoppmann et al., 2014). Unlike Binz et al.'s (2016) research, this research focuses on not only the path creation stage but also the entire evolution process of an industry. Therefore, the market is not regarded as a resource in this study. Instead, this study focuses on the three key resources of knowledge, financial investment, and legitimacy.

2.3. Analytical framework

Bringing key concepts together, Figure 1 presents the analytical framework of this research. This framework offers both a multilevel and an evolutionary interpretation: it places a central focus on the verticality of policy mixes and depicts the coevolutionary process of policy mixes and industrial path development towards sustainability transitions.

Figure 1. Analytical framework. (Source: drawn by the author)

In the framework, the multilevel policy mix plays a central role, encompassing the dynamic relationships between different policy packages within a broader policy frame. Specifically, the framework highlights the vertical interactions between the elements (policy strategy and policy instrument) and the processes (policymaking and policy implementation) of policy mixes at national, regional, and urban levels. The key message is that, policy mixes that enable industrial path development of a region exhibit significant verticality. Industrial path development is viewed through the anchoring of key resources. This perspective of resource anchoring, although originated in the TIS framework (Binz et al., 2016), possesses significant advantages in the analysis of the coevolution of policy mixes and innovation systems because of a conceptual disentangling of policy mixes from TIS functions, as previously called for by scholars (Reichardt et al., 2016). Given that

resources can be obtained from both within the region and outside the region (see, for instance, Binz et al., 2016; Huang et al., 2016; Trippl et al., 2017), this study considers both types of resources. The term 'anchoring' in this research refers to the mobilization and recontextualization of both regional and extraregional resources in a particular technological field within the region. After a long, dynamic and often arduous process, the development of a green industry might eventually lead to broader and fundamental socio-technical changes, enabling sustainability transitions of the region (Bridge, et al., 2013).

The process presented in figure 1 will be examined in an illustrative case of SWH industry in Shandong Province in China. Through a coding system (refer to details in Section 3.2), the elements and processes of multilevel policy mixes and key resource flows are embedded and highlighted in the storyline presented in Section 4.2.

3. Study area, data and method

3.1. Shandong Province and the SWH industry

This study uses the case of SWH industry in Shandong Province in China as an empirical illustration of the verticality of policy mixes in industrial path development towards sustainability transitions.

By definition, the SWH industry is represented by a collection of firms that focus on the application of SWH technology in their production activities. SWH technology uses solar collectors to absorb incoming solar radiation and convert it to heat energy. Such heat is conveyed through a working fluid (air, water, refrigerant) and can be used to heat water for washing and other domestic uses (Buker and Riffat, 2015). China has been leading in the global solar thermal market for several years (Islam et al., 2013). In 2015, China accounted for 71% of the total installed thermal capacity in the world (Wang et al., 2015; Weiss et al., 2017). The case region of this study, Shandong Province, is one of the major production bases of SWH systems in China (Luo and Huo, 2003).

Shandong Province is located on the eastern edge of the North China Plain. There are 17 cities under the jurisdiction of Shandong Province, with Jinan as the capital city (see figure 2). Figure 3 shows the annual output of SWH systems (calculated by the surface area of solar collectors) in Shandong and China from 2008 to 2016. The SWH output in Shandong accounted for more than 30% of the total output in the country. According to the China Brand Power Index in 2017, of the top ten brands of SWH systems, five were based in Shandong[1].

Figure 2. Administrative map of Shandong Province. (Source: National Geomatics Center of China)

Figure 3. Annual output of solar water heaters in Shandong and China (2008 to 2016)[2] (Source: drawn by the author)

This research seeks to present a representative case to illustrate the role of multilevel policy mixes in the path creation and development of an industry that eventually (to a certain extent) drives sustainability transitions in a region. The rationale behind the selection of the SWH industry in Shandong is twofold. First, Shandong is recognized in the transition literature as a region in which the deployment and dissemination of SWH technology has proven to induce fundamental transformations (Goess et al., 2015). City-level socio-technical transitions around the technology are already taking shape. Scholars have documented SWH technology's embeddedness in local economies, infrastructure and social practices in cities such as Dezhou (Li et al., 2011; Yu and Gibbs, 2018a, 2018b) and Rizhao (Bai et al., 2009; Huang et al., 2018a). Second, the rise of the SWH industry in Shandong Province offers a rich empirical case in which policy intervention has played an

[1] http://www.chn-brand.org/c-bpi/taiynrsq1.html

[2] The data of Shandong in the years 2011, 2012, 2014, 2015 and 2016 were the annual output of key enterprises. Therefore, the total output of Shandong Province is expected to be higher than the data shown in the figure.

active role, and there exist dynamic interactions between multilevel policy mixes. Since 2004, policy initiatives at both the city and province levels have demonstrated strong support for the sector. For instance, Shandong was one of the first provinces in China to enact favourable policies for the development of SWH technology. In particular, mandatory installation policies in several cities in Shandong have fuelled the substantial market expansion of SWH technology in urban areas. A combination of these characteristics has made the SWH industry in Shandong Province an ideal and illustrative case to study the vertical interactions of multilevel governments in shaping regional industrial path development towards sustainability transitions.

3.2. Data collection

I first conducted a general review of the policy documents related to the SWH industry from the websites of multilevel governments, in which 255 relevant policy documents were reviewed. A database was established with the relevant policies. In the database, multilevel policy mixes are classified into and coded as 12 categories (Table 1). The results of the document analysis are presented in Section 4.1, with an overview of the multilevel policy mixes for the SWH industry in Shandong Province. Moreover, in Section 4.2, the key elements and processes of multilevel policy mixes are extracted from the database and are highlighted in the description of the development of the SWH industry, presenting the coevolution of the multilevel policy mixes and industrial path development.

Table 1. Coding for multilevel policy mixes

To examine the role of multilevel policy mixes in the process of industrial path development, I used a combination of expert interviews and event history analysis (Negro et al., 2007; Reichardt et al., 2016). I conducted a total of 18 expert interviews in different fields related to the SWH industry. The valuable information gained from these interviews helped in tracing the course of events. Table 2 presents background information on the interviewees. Expert interviews were complemented by an event history analysis of data sources, such as professional journals, newspapers, and websites. The main aim of the event history analysis was to retrieve as many historical events as possible relevant to the SWH industry to serve as corroborative evidence for information gained from the interviews. I selected three types of data sources, including a professional journal that specializes in the solar industry (‘*Solar Vision*’), a national journal that reports on extraregional (national and global) events related to the Shandong SWH industry (‘*Solar Energy*’), and two local newspapers that focus on provincial and city events in Shandong Province (‘*Jinan Daily*’ and ‘*Dezhou Daily*’). Moreover, based on these resources, a snowballing method led me to several other major national and provincial newspapers and journals, such as the ‘*People’s Daily*’ (national), the ‘*Dazhong Daily*’ and ‘Qilu Evening News’ (provincial). Events related to the resource flows of industrial path development were entered into a database, and these resources were classified into and coded as six different types (Table 3). The key events gained from these sources are highlighted in the empirical results in Section 4.2.

Table 2. Overview of expert interviews

Table 3. Coding for regional and extraregional resources

4. Empirical analysis

4.1. An overview of multilevel policy mixes for the SWH industry in Shandong

The government document analysis shows that multilevel policy mixes regarding the SWH industry in Shandong have emerged over the past decade.

After the Kyoto Protocol, several laws and bylaws related to climate change were enacted at both the national and provincial levels, such as the national ‘Renewable Energy Law (RE-Law)’, the ‘Residential Building Energy Conservation Bylaw (RBEC-Bylaw)’, and the provincial ‘Rural Renewable Energy Bylaw (RRE-Bylaw)’. These laws and bylaws legitimized the development and application of

renewable energy and energy conservation technology and products, and they undoubtedly paved the way for the legitimization of solar thermal technologies. Following the enactment of the 'Guidance for Renewable Energy Building (REB-Guidance)' in 2006 and the 'Guidance for SWH Industry (SWH-Guidance)' in 2007 at the national level, several elaborate schemes were put forward at the provincial level to facilitate SWH application, such as Shandong's financial subsidy (SWH-Subsidy).

At the urban level, key instruments have been designed to address the installation of SWH systems in buildings. As early as 2004, even before the launch of policy instruments that highlighted the development of the SWH industry at the provincial and national levels, a regulation for the mandatory installation of SWH was formulated in Ju County in the city of Rizhao (SWH-Mandatory Control-Ju County). After that, urban initiatives for the mandatory installation of SWH proliferated in Shandong (e.g., Rizhao, Jinan, Yantai, Qingdao, and Zibo).

Figure 4 presents an overview of key policy strategies and instruments at different governance levels. Section 4.2 further elaborates on multilevel policy elements and processes for the SWH industrial path evolution.

Figure 4. Development of the elements of the policy mix for SWH industry in Shandong Province over time (Source: drawn by the author)

4.2. The coevolution of multilevel policy mixes and the SWH industry in Shandong, China

Early development of the SWH industry in Shandong Province was initiated mainly through grassroots resource exploitation. Before 2004, hardly any provincial government documents supported this sector. The unmet social need for domestic hot water use implies a huge potential market for SWH systems. Start-up firms began to emerge in the late 1980s and the 1990s, such as Sangle (founded in 1987) and Himin (founded in 1995) (Goess et al., 2015). These pioneering firms have played a crucial role in channelling various resources into the SWH sector. Gradually, a niche market opened up.

It is worth noting that successful early-stage resource exploitation is inseparable from pre-existing endowments in Shandong Province, such as abundant solar resources, a knowledge base and related industries. Shandong Province is a region with good solar resources (Zhao et al., 2013), which serve as an initial natural advantage for the application of SWH technology. Moreover, pioneer entrepreneurs have made good use of local contacts, networks, and related knowledge bases (Feldman, 2003). For instance, Sangle was based on the Solar Energy Laboratory affiliated with the Energy Research Institute of the Shandong Academy of Sciences. The Solar Energy Laboratory was established in 1982 and is one of the earliest research centres in China to specialize in the R&D of SWH technology. Sangle's founder, Jingping Gao, was a researcher in the energy research institute, and his team was also formed primarily by researchers from the Solar Energy Laboratory (Dazhong Com, 2008). Another leading SWH enterprise in Shandong, Linuo Paradigma, was formed jointly by a local firm, Linuo, and a German firm, Paradigma. The predecessor to Linuo was a firm that had seven years of experience in manufacturing SWH-related rough pipes and vacuum tubes (Solar Vision, 2011).

However, in the absence of government intervention, the establishment of legitimacy as a resource encountered substantial difficulties. Because there was no industry standard, the quality of the SWH products could not be guaranteed. Consequently, unsatisfactory user experiences with unqualified products affected local trust in and acceptance of the SWH technology. To change this situation, SWH entrepreneurs and intermediary organizations engaged in various lobbing activities (Interview, Intermediary). Since 2004, multilevel policy mixes that significantly influenced the anchoring of multiple resources began to emerge. In what follows, I present the coevolution process of multilevel policy mixes and the SWH industry in Shandong from 2004 to 2016, which was divided into three phases based on key events. In the empirical analysis, interview materials served as a

main source of data to guide the journey of the story. More relevant quotes for key events in each phase can be found in the Appendix.

Phase 1. *Emergence of multilevel policy mixes and steady resource mobilization and anchoring (2004–2008)*

Beginning in 2004, the emergent multilevel policy mixes resulted in a gradual process of resource accumulation, which led to the embryonic formation of industrial clusters and increasing social acceptance. Until 2008, the SWH industry in Shandong had been on a track of steady and healthy development.

Early in 2004, a proposal for the mandatory installation of SWH systems in residential buildings was first put forward at a regular meeting of the Bureau of Housing and Urban-Rural Development in Ju County of Rizhao. Although no official governmental document was issued, this regulation was believed to be the first governmental regulation specifying the application of SWH technology (Interview, Government). The mandatory regulation was implemented quite strictly in Ju County, greatly driving the popularization of SWH technology. As recalled by a former government official,

> *"The regular meeting of the Bureau of Housing and Urban-Rural Development came up with a meeting briefing document with the decision of mandatory installation of SWH systems. This document was then distributed to every real estate developer (P.Impl-U)…" (Interview, Government)*

Mandatory regulations regarding the installation of SWH systems in buildings were later issued in Rizhao, followed by several cities in Shandong, such as Jinan, Yantai, Qingdao and Zibo. This initiative launched by Rizhao proved to have a demonstration effect on subsequent regulations at both the urban and provincial levels, as vividly reflected by the proud tone of a Rizhao government official's discussion of the topic:

> *"At that time, the Rizhao municipal government issued the document for building-integrated SWH systems [SWH-Mandatory Control-Rizhao]… It was me who drafted the document…We were the first in Shandong to enact such regulations, and government officials from Shandong and other cities all came to Rizhao to learn about our experience." (Interview, Government)*

The city of Dezhou is also worth noting. As early as 2005, the Dezhou Municipal Government launched the 'Solar City Strategy' (*P.S-U*). Around this city-level policy strategy, a series of policy instruments were formulated ('Rural application-Dezhou' and 'Industry support-Dezhou' in figure 4) (*P.In-U*) (Dezhou Daily, 2006). A strategy committee was also formed by relevant government departments to ensure further policy support and the smooth promotion of the 'Solar City Strategy' (*P.Mak-U, P.Impl-U*). Later, that year, Dezhou was officially pronounced the 'Chinese Solar City' by the China Renewable Energy Society (*R.legit-E*) (Dezhou Daily, 2010). Moreover, an SWH industry cluster around Himin began to form in Dezhou. A Dezhou government official described the following:

> *"The provincial government took this [Dezhou's designation as the 'Chinese Solar City'] very seriously. After all, there is only one [Chinese Solar City] in the whole country. Of course, it is also because that the industry contributed greatly to the local economy." (Interview, Government)*

Following these city initiatives, the provincial government began to stimulate the province-wide development of the SWH market. For example, in 2007, the provincial government provided subsidies to public buildings (hotels, schools, hospitals, etc.) for the installation of SWH systems (*P.In-P*).

Meanwhile, at the national level, two national government documents highlighted the implementation of building-integrated SWH systems in 2006 and 2007 (*P.S-N*) (see figure 4), which

clearly defined the duties of the corresponding bureaus of lower-level governments during the implementation process. These duties had a marked contrast with the vague obligations and responsibilities of governmental bureaus before 2004, implying an increasing coherence in policymaking and implementation processes. These two strategies, together with many national standards and legal regulations related to building-integrated SWH systems in force since 2006 (*P.In-N*), mirrored a steady step towards a more regulated market, which further strengthened the legitimacy of the SWH industry (*R.legit-E*).

In addition, the government injected substantial financial resources into the industry. In 2006, the 'National Demonstration Projects of Renewable Energy Buildings' was launched (*P.In-N*). Of the first group of 25 projects, 5 settled in Shandong (*R.investm-E*) (Liu, 2006) not only due to Shandong's leading position in the SWH industry but also as a result of institutional support from the provincial government. For instance, after the announcement of this national project, the Shandong Provincial Department of Construction organized several seminars with SWH enterprises to encourage and help them apply for national subsidies (*P.Impl-P*). An executive of an SWH enterprise indicated the following:

> *"I remember I went to Jinan several times. They [government officials at the Shandong Provincial Department of Construction] really wanted us to apply… It was somewhat troublesome because you need to pull a few strings. However, at that time, it [the national subsidy] was indeed a lot of money." (Interview, Manufacturer)*

In 2007, another national-level scheme was the 'State Housing Industrialization Demonstration Base' (SHIDB), which aimed to facilitate the innovation and industrialization of new technologies related to building construction (*P.In-N*). Among only five enterprises awarded the designation, Linuo Paradigma was the sole SWH enterprise (*R.legit-E, R.investm-E*). The intention of the scheme was to highlight Linuo Paradigma's demonstration and instructional role in the development and application of building-integrated SWH systems in commercial and residential buildings and to form an industry chain of SWH technologies and products related to the building sector, which indicates that building-integrated SWH technology has been viewed by the central government as a key technology to advance energy savings in buildings.

Following national guidance, the Shandong provincial government seized the opportunity and enacted a series of strategic plans and instruments to develop the SWH industry. In 2007, the Shandong Bureau of Housing and Urban-Rural Development, together with Linuo Paradigma, enacted the first provincial-level technology standard for the design and application of building-integrated SWH systems (*P.In-P*); this standard provided principles for the integration of SWH systems into various types of buildings in Shandong (Jinan Daily, 2008). Later, in 2008, the 'Development Plan for the Application of Renewable Energy Buildings in Shandong (2008-2012)' was announced (*P.S-P*), in which special attention was paid to the popularization of building-integrated SWH systems, as well as the further development and upgrading of the SWH industry in the region. Obviously, the legitimacy of SWH in Shandong was initially formed through these actions (*R.legit-R*).

With the emergence of multilevel government support, an industrial cluster was forming in Shandong, especially in Dezhou and Jinan, where Himin and Linuo Paradigma were located. In 2007, there were more than 110 SWH manufacturers in Shandong (Department of Construction of Shandong, 2008). In 2008, the SWH output in Shandong constituted 30% of the total output in China; of the 30 Chinese enterprises with an annual output value of above 100 million CNY (approximately 14.39 million USD[3]), ten were located in Shandong (Li and Qing, 2009; Wang and Wang, 2010). The SWH systems were being used by increasingly more households, and the social acceptance of this product was becoming gradually strengthened and anchored, implying the formation of legitimacy

[3] The World Bank's annual official exchange rate for USD to CNY (1 USD to CNY) in 2008 was 6.9487; see https://data.worldbank.org/indicator/PA.NUS.FCRF.

from the perspective of consumers and society (*R.legit-R*). However, the SWH industrial clustering in Shandong was still at an early stage. Although many types of equipment, such as stamping equipment, welding equipment and vacuum equipment, were designed and supplied domestically, certain key technologies were lagging behind advanced international levels and were still being imported from abroad (Hu et al., 2012). For instance, Linuo Paradigma imported the technology of wall-mounted SWH systems from Germany to address the technical challenges of installing SWH systems in high-rise buildings (Jinan Daily, 2008) (*R.knowl-E*).

Phase 2. *Global financial crisis, a sudden change in national priorities, and the unbalanced mobilization of resources (2009–2011)*

In the second phase, the steady and healthy development of the previous phase was replaced by the over-exploitation of rural market and irrational expansion of the SWH industry triggered by dominant national demand-pull policy supports, leading to an unbalanced mobilization of resources.

While governmental support continued to be implemented and strengthened in Shandong, due to the influence of the global financial crisis in 2008, the General Office of the State Council launched a 4 trillion CNY (approximately 575.65 billion USD) economic stimulus program ('Consumption Expansion Guidance' in figure 4), in which the 'Home Appliances to the Countryside' (HATC) scheme (*P.In-N*) greatly influenced the trajectory of development of the SWH industry (Jinan Daily, 2010).

The HATC scheme was aimed at encouraging residents in rural areas to buy government-subsidized home appliances; it was hoped that sales in the countryside could help with the overcapacity of home appliances to offset the impacts of the global financial crisis. In 2009, SWH products were listed in the government procurement inventory for HATC. After a public tender, 92 SWH enterprises were awarded a tender, and Shandong was the region with most enterprises (20 of the 92) (*R.legit-E*). As a complementary instrument, the 'Operating Rules for HATC' was announced (*P.Impl-N*). Shortly afterwards, the Shandong provincial government and several urban governments issued specific operating rules for policy implementation (*P.Impl-P, P.Impl-U*) (Cheng, 2009). Because subsidies for HATC were provided mainly by the national government, the role of lower-level governments was to promote coordination in policy implementation. Taking the city of Jinan as an example, the municipal government made substantial efforts to improve the logistics and distribution system and to simplify the procedures for subsidy application to ensure the smooth implementation of the HATC scheme (*P.Impl-U*) (Jinan Xinhua News, 2009). As recalled by a government official,

> *"The money from the national government [subsidies for HATC] was allocated from higher-level governments. Our job is to make sure that the money goes to the farmers." (Interview, Government)*

The HATC scheme has been proven to exert a great influence on the development trajectory of the SWH industry in Shandong. A direct consequence was the shift in the target market from urban areas to the rural areas. As one interviewee described,

> *"During that three years [2009 to 2011], where did everyone rush to, like a swarm of bees? The rural areas." (Interview, Intermediary)*

Moreover, huge financial resources were invested in the SWH sector. For instance, in 2009, Sangle signed a cooperative agreement with the Standard Chartered Bank for an investment of 23.3 million USD (*R.investm-E*). The implementation of the HATC helped promote further clustering of the SWH industry in Shandong. In 2008, there were 387 SWH-related enterprises in Shandong, increasing to 523 in 2009 (Qilu Evening News, 2010).

However, the unbalanced focus of the HATC policy arrangements on the demand-pull instruments resulted in a less comprehensive policy mix. From 2009 to 2011, except for the national HATC scheme and relevant implementing rules at the national, provincial and urban levels, hardly

any other policy strategies and instruments were implemented – in strong contrast to the previous phase from 2004 to 2008. This shift caused an uneven distribution of various resources and generated rather mixed effects on resource anchoring. In contrast to the unprecedented mobilization of financial resources, little knowledge development occurred during this phase, and the legitimation of SWH technology even declined. Through irrational expansion, the long-term health of this industry was substantially jeopardized, and many problems appeared. For instance, due to the absence of clear and comprehensive industry standards, the threshold of market entry was very low. At that time, because demand greatly exceeded supply, all firms that entered the industry could make money by simply spending several thousand USD to register a trademark and start producing SWH products. As one manufacturer reported,

> *"The year of 2009 was a crazy year. At that time, anyone who registered a trademark could enter the market and could sell pretty well." (Interview, Manufacturer)*

As such, many small enterprises with an informal 'family workshop' management style entered the industry. Large numbers of unqualified products were produced by these small enterprises. As described by one interviewee,

> *"They [small enterprises] just rushed up headlong to the rural market and disrupted the market order. The price was down, and the quality of products could not be guaranteed." (Interview, Intermediary)*

Problems generated by these unqualified products seriously endangered the social acceptance of the SWH products that had been established by pioneer enterprises (*R.legit-R*). In reaction to this chaotic situation, many industry representatives in Shandong called for the formulation of industry standards to restore market order. Obviously, there was an urgent need for policy adjustments to change this situation.

Phase 3. *Policy mix reconfiguration, further resource consolidation and anchoring, and industry shakeout and concentration (2012–2016)*

The last phase is characterized by the improvement of multilevel policy mixes with more comprehensive and balanced accounts of both urban and rural areas. The national and provincial policy mixes have been optimized to better regulate the market with an agenda to support the scale-up development of large manufacturers, leading to the closure of a number of small factories and to an increase in the general industry concentration ratio in Shandong Province.

With the termination of the HATC scheme in 2012, a series of policy documents aimed at regulating the SWH market were published. This move triggered an industry shakeout, and many small, unqualified enterprises went bankrupt during this process. In September 2012, the first mandatory national standard for the SWH industry (*P.In-N*) was enacted. In this document, three different quality levels were classified based on energy efficiency, and SWH products had to reach at least the lowest level to be allowed to enter the market.

Additionally, in 2012, SWH products were included in another national subsidy scheme, the 'Energy Saving Subsidy Project' (ESSP, *jie neng hui min gong cheng*), which was regarded as an alternative to the HATC scheme. Approximately 15% of the total subsidy (26.50 billion CNY, approximately 4.20 billion USD[4]) was planned for allocation to SWH products (*P.In-N*). In contrast to the low entry threshold of the HATC scheme, enterprises participating in this project had to meet strict entry criteria. Instead of the 92 SWH enterprises that were awarded a tender in the first round of the HATC, only 20 enterprises entered the first round of the ESSP, nine of which were from Shandong (*R.legit-E*), which demonstrates the increased concentration of the SWH industry both in

[4] The World Bank's annual average middle exchange rate for USD to CNY (1 USD to CNY) in 2012 was 6.3123; see https://data.worldbank.org/indicator/PA.NUS.FCRF.

the country and in Shandong. It is worth noting that during the design of this policy, seminars were organized by the Ministry of Industry and Information Technology (MIIT), inviting government officials from key provinces and cities (including Shandong Province and the city of Qingdao in Shandong) of HATC implementation to discuss the outcomes of the scheme and to solicit suggestions for further policy formulation (China Securities Journal, 2012). Thus, the policy learning and reconfiguration at the national level was greatly informed by lower-level governments, particularly those in Shandong Province.

Moreover, with an increasing understanding of the industry and growing experiences in the policy effects of different instruments, MIIT announced 'Guidelines for the Implementation of the Healthy Development of the SWH industry' in 2013, where Shandong was highlighted as one of the key regions for industrial upgrading (*P.S-N*) (MIIT, 2013). The intention was that different resources could be concentrated in major manufacturers in the future development of the SWH industry (China Securities Journal, 2013). Following the national guidelines, in 2014, the Shandong provincial government issued the 'Guidelines on Accelerating the Application of the SWH System and Deepening the Transformation of the SWH Industry', urging changes to address the overcapacity of low-end products (with an energy efficiency level of below 3) and to cultivate 10 key enterprises (*P.S-P*) (Shandong EITC, 2014). Complementary instruments were enacted under this guideline ('SWH Application and Industry-Demonstration' in figure 4) (*P.In-P*). The provincial guidelines were then delivered to and implemented by urban governments. Thus, the national strategy on SWH industry development directly influenced policymaking in Shandong Province and was then implemented by lower administrations. One government official described the following:

> *"As long as there are documents from the central government, we [the provincial and city governments] both need to carry out the task, without a doubt. What we can do is to, according to practical conditions (local contexts), formulate the detailed rules and regulations for better implementation of the policy (from the central government), to achieve the targets." (Interview, Government)*

Meanwhile, urban policy initiatives again emerged as the mandatory installation of building-integrated SWH systems has been implemented and strengthened in an increasing number of cities in Shandong. In 2014, the Jinan Municipal Government extended its mandatory regulations from residential buildings of 12 floors or lower (in 2007) to residential buildings of below 100 meters (equivalent to 33 floors) (*P.In-U*). Further enforcement of the mandatory regulations has opened up a new market, the so-called 'construction project market', in which contracts are often directly signed between real estate developers and SWH manufacturers to install SWH products for a newly built neighbourhood as a whole (Guo, 2014). The growing expectations for this new market segment have driven the inflow of capital resources into the industry. Two SWH manufacturers from Shandong were listed in the year 2012: Lecron Energy Saving Materials Co., Ltd., was listed on the Shenzhen Stock Exchange (Dazhong Com, 2012), and Auhua was listed on the London Stock Exchange (*R.investm-E*) (Dazhong Daily, 2012). Many small manufacturers lack the resources to participate in these relatively large projects, which has, to a certain extent, facilitated the consolidation of resources in large enterprises.

However, the enterprises still focused largely on market expansion and the scaling up of production, while technology innovation and knowledge development lagged. As one interviewee stated,

> *"It has been so many years, but the industry sees no innovation, no changes. The structure of the product is still more or less the same, and user experience has not been improved. These problems never really get solved." (Interview, Intermediary)*

4.3. Discussion of the results

Figure 5 presents an overview of the coevolution of multilevel policy mixes and the SWH industry in Shandong. The emergence of multilevel political support since 2004 has facilitated steady resource consolidation in the SWH sector. However, the policy leap forward after the global financial crisis, particularly the HATC scheme that was launched in 2009, has resulted in an unbalanced mobilization and accumulation of resources. Responding to this chaotic situation, starting in 2012, multilevel policy mixes have been adjusted to consolidate the anchoring of resources in key enterprises and to increase industry concentration.

Figure 5. Phases of SWH industrial path development and interactions of multilevel policy mixes (Source: drawn by the author)

The empirical case demonstrates dynamic interactions of multilevel policy mixes in the path development of the SWH industry in the Shandong region.

Before 2004, the SWH industry in Shandong was initiated mainly through grassroots resource exploitation. Pioneer regional anchors (primarily entrepreneurs) called for market order for further resource mobilization. As a response, multilevel policy mixes began to emerge in 2004. In the first phase, both the urban government and the central government played active roles in resource mobilization and anchoring, while the provincial government played a relatively more passive role and acted mostly as a follower. On the one hand, urban initiatives informed policymaking at the provincial level; on the other hand, the provincial government followed the national emphasis on the development of the SWH industry. Therefore, the vertical interaction of policy mixes in this phase exhibits both top-down (state-to-province) and bottom-up (city-to-province) patterns (figure 5, phase 1). The interactive mechanism remains unidirectional, with the provincial government being the main recipient of influences.

In the second phase, a leap forward in policymaking at the national level (the HATC scheme) and corresponding policy mixes at lower levels significantly reversed the steady and healthy development that occurred during the previous phase. Although a large rural market was opened up, an uneven development of resources was induced, as manifested by the massive inflow of financial investment on the one hand and the stagnation or even decrease in technology innovation and legitimacy on the other. The observed interaction at this stage occurred mainly through a unidirectional, top-down mechanism (state to province to city) (figure 5, phase 2), which indicates that when there is a sudden change in national priorities, the central government can play a dominant and decisive role in shaping (or reshaping) the direction of policymaking and implementation at lower levels of governance. Moreover, from the components of policy mixes, it can be seen that national policy instruments are often complemented by corresponding measures for policy implementation at lower governance levels, while initiatives of policymaking are largely absent. In other words, the role played by lower-level governments in this phase was more of policy practitioners than of policymakers, which results in a relatively lower comprehensiveness of multilevel policy mixes.

In the last phase, a process of policy learning and reconfiguration is observed. Adjusted multilevel policy arrangements elevated the threshold of market entry, which encouraged the concentration of varied resources in large manufacturers. National-level policy adjustments on the one hand were made possible with inputs from lower-level governments and on the other hand provided instructions for adjustments to provincial and urban policy mixes. These interactions represent a mechanism of vertical policy learning, which, unlike previous phases, showed a bidirectional pattern and eventually formed a feedback loop (figure 5, phase 3). There is clearly a growing comprehensiveness of multilevel policy mixes, in which policy strategies are designed with clearer objectives and plans, and various policy instruments enable the operationalization of these policy strategies.

It can be seen that multilevel interactions of policy mixes are not confined merely to the political system but also interact dynamically with the resource anchoring process. That is, the interactive

dynamics unfold only in the coevolutionary process of policy mixes and industrial path development. In this process, we see the significant role played by multilevel policy mixes in the mobilization and anchoring of various resources. Specifically, institutional support through the design of long-term policy strategies (e.g. Dezhou's 'Solar City Strategy') is a strong source for the development of legitimacy; demonstration projects, especially those at the national level (e.g. the designation of Linuo Paradigma as 'State Housing Industrialization Demonstration Base'), often indicate the injection of substantial financial resources; and government-mandated strategies and instruments can help the opening up of new market segments (e.g. the opening up of the rural market under the HATC scheme and the opening up of the 'construction project market' by the mandatory installation of SWH systems in high-rise buildings), that further drives the expansion of business and the channelling of new investment and knowledge into the industry. With the popularization of SWH technology, key resources have been successfully recontextualized in the region, leading to the embeddedness of SWH technology in local economies, infrastructure and social practices. For instance, in many rural areas in Shandong Province, the possession of an SWH system is now regarded as a symbol of social status, and it is even listed as one of the 'must-have items' for married couples, alongside a colour TV and a washing machine (Huang et al., 2018a). Thus, broader and deeper socio-technical changes have been generated by the development of the SWH industry in the region, representing manifestations of a sustainability transition.

5. Conclusion

In the field of sustainability transitions, there is an increasing recognition of the significance of policy mixes for stimulating technological innovation and new industries. In extant literature, the vertical or multilevel dimensions of policy mixes have not been sufficiently addressed (Howlett et al., 2017). Moreover, the verticality of policy mixes is rarely examined within the co-dynamics of policymaking and the socio-technical system. This study bridges this important gap and investigates the vertical interactions of policy mixes in the process of industrial path development towards sustainability transitions. An analysis of the exemplary case of SWH technology in Shandong Province in China revealed both the bottom-up and top-down processes of interactions. On the one hand, city-level policy initiatives can inform higher-level policymaking (bottom-up process); on the other hand, national priorities can significantly shape and reshape policy mixes at lower levels of government (top-down process). The urban government and the central government have played more active roles in resource mobilization and anchoring than the provincial government. Moreover, with the coevolution of policy mixes and the SWH industry, the vertical interactions of policy mixes evolve from unidirectional, top-down or/and bottom-up patterns toward more complex bidirectional ones through a vertical policy-learning feedback mechanism. This finding casts new insights into the emerging body of literature that attempts to uncover the interdependency of policy mixes and innovation systems (Reichardt et al., 2016). The finding shows that, with the anchoring of resources and the growth of the industry, not only is the policy mix developing, but its verticality is also evolving and maturing.

A major limitation of this study is that it presents only one single case in China. Apparently, the richness and variety of the empirical analysis could be strengthened with comparative case studies in different contexts. Particularly, the characteristics of China's political system need to be taken into consideration in the interpretation of some of the results generated in the empirical analysis. For instance, under China's authoritarian institutions, governmental support *per se* often represents a strong source of legitimacy. Nevertheless, this might not be the case under more democratic political systems.

However, although this research is based on only one empirical case of the SWH industry in Shandong Province, the findings provide broader implications for other contexts.

First, significant vertical interactions among multilevel governments indicate the need to develop more nuanced perspectives on the design of policy mixes. Although hierarchical power structures

might vary in different contexts (for instance, in the Chinese context, the national government possesses strong abilities and leadership to achieve political objectives and influence decision making in subnational governments, while in Western contexts, regional regulations can be more influential than national-level policy priorities), the interplay of policy interventions at multiple scales has been well proven (see also Dawley, 2014; Dawley et al., 2015). Notably, while the national government possesses a broader and longer-term vision of national development priorities, subnational (especially urban-level) governments are equipped with valuable knowledge of regional and urban contexts, which is often particularly relevant for the sustainability transitions in a region. To this end, in the coordination of multilevel policy mixes, the role played by the regional government needs to be strengthened to aim the flow of resources towards the field that best matches the place-based endowments. A recent study, for instance, shows how a state-designated demonstration city failed in SWH implementation due to a mismatch between technological characteristics and local contextual factors (Huang et al., 2018b). Therein, more nuanced design of policy mixes is conducive to the development of a positive vertical feedback mechanism, which is open to responsive inputs of governance knowledge from different levels of governments and grants more flexibility in the search of transition pathways.

Second, this study questions the static view of policy mixes that denies potential conflicts and tensions and neglects the temporal and coevolutionary nature of the policymaking process (Matti et al., 2017). As suggested by Flanagan et al. (2010), “it is unrealistic to seek to identify unambiguously “good” policy mixes for innovation”. The policy mix evolves along with the industry and exerts influence through a dynamic policy learning and adjusting process (Hoppmann et al., 2014; Matti et al., 2017). The evolution of the interactive patterns of multilevel policy mixes uncovered in this study adds more complexity to the coevolutionary process. Therefore, the analytical framework presented in this study is of relevance beyond this single case and is worth testing in other contexts. Conceptually, the perspective of viewing innovation and industry path development through resource anchoring disentangles policy mixes from TIS functions and thus provides more conceptual clarity to the analysis of the relationship between policy mixes and innovation systems. Theoretically, the framework provides a multilevel and an evolutionary interpretation of policy mixes. The multilevel and the transient nature of policy mixes is currently undertheorized and underresearched. The framework caters to the need to address this important knowledge gap and offers a new and useful analytical tool that can readily be used in more empirical studies.

This study proposes the following avenues for future research. First, more conceptual and empirical research on the vertical dimension of policy mixes within multiple contexts is urgently needed. This study shows that even within the political system of China, a country characterized by authoritarian governance, there are active bottom-up interactions among policy mixes. It is therefore safe to assume that within more democratic regimes, more dynamic multilevel interactions can be observed, which could enrich our understanding of the varieties and complexities of interacting mechanisms between multilevel governmental agencies in innovation policymaking. Second, a more systematic evaluation of the characteristics of policy mixes is needed, particularly from a multilevel, evolutionary point of view (Rogge and Reichardt, 2016; Reichardt and Rogge, 2016). Characteristics of policy mixes manifest during the dynamic interactions between policy elements and processes. This study observes that policy mix interactions evolve over time. It would be intriguing to examine whether the characteristics of policy mixes also exhibit certain evolutionary patterns. Finally, SWH technologies with differing characteristics are not differentiated in this study. More nuanced research is needed to shed light on the variations between different (or even competing) technologies and their effects on industry localization (see, for instance, Schmidt and Huenteler, 2016).

Reference

Asheim, B.T. and Gertler, M.S., 2005. The geography of innovation: regional innovation systems. In: Fagerberg, J., Mowery, D.C. and Nelson, R.R., eds. *The Oxford handbook of innovation*. New York: Oxford University Press, pp.291-317.

Bai, X., Wieczorek, A.J., Kaneko, S., Lisson, S. and Contreras, A., 2009. Enabling sustainability transitions in Asia: the importance of vertical and horizontal linkages. *Technological Forecasting and Social Change*, 76(2), pp.255-266.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., and Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: a scheme of analysis. *Research Policy*, 37, pp.407-429.

Binz, C., Truffer, B. and Coenen, L., 2016. Path Creation as a Process of Resource Alignment and Anchoring: Industry Formation for On-Site Water Recycling in Beijing. *Economic Geography*, 92, pp.172-200.

Bressers, H.T.A. and O'toole, L.J., 2005. Instrument selection and implementation in a networked context. *Designing government: From instruments to governance*, pp.132-153.

Bridge, G., Bouzarovski, S., Bradshaw, M. and Eyre, N., 2013. Geographies of energy transition: Space, place and the low-carbon economy. *Energy Policy*, 53, pp.331-340.

Buker, M.S. and Riffat, S.B., 2015. Building Integrated Solar Thermal Collectors–A Review. *Renewable and Sustainable Energy Reviews*, 51, pp.327-346.

China Securities Journal, 2012. 工信部召开家电下乡座谈会 酝酿家电扶持后续政策 [The Ministry of Industry and Information Technology organizes HATC seminar to discuss future policies to support home appliances]. Available at: http://finance.ifeng.com/stock/bk/20121107/7261786.shtml (in Chinese).

China Securities Journal, 2013. 太阳能热水器行业集中度将提升 [The concentration rate of the solar water heater industry has increased]. Available at: http://finance.qq.com/a/20130307/000366.htm (in Chinese).

Cheng, H.Z., 2009. 太阳能下乡几成定局 [The die is almost cast for solar water heaters to be included in HATC scheme]. *Solar Vision*, 7, pp.16-17 (in Chinese).

Crevoisier, O. and Jeannerat, H., 2009. Territorial knowledge dynamics: from the proximity paradigm to multi-location milieus. *European Planning Studies*, 17(8), pp.1223-1241.

Dawley, S., 2014. Creating new paths? Offshore wind, policy activism, and peripheral region development. *Economic Geography*, 90(1), pp.91-112.

Dawley, S., MacKinnon, D., Cumbers, A. and Pike, A., 2015. Policy activism and regional path creation: the promotion of offshore wind in North East England and Scotland. *Cambridge Journal of Regions, Economy and Society*, 8(2), pp.257-272.

Dazhong Com, 2008. 桑乐太阳能的四大“军规” [Four rules for solar water heaters of Sangle]. Available at: http://www.dzwww.com/shandong/sdnews/200809/t20080918_3964163.htm (in Chinese).

Dazhong Com, 2012. 联创节能:关于完成工商变更登记的公告 [Lianchuang Energy Saving: Public notice on the completion of the change of business registration]. Available at: http://finance.dzwww.com/licai/gupiao/sdgg/201210/t20121012_7514080.html (in Chinese).

Del Rio, P., 2014. On evaluating success in complex policy mixes: the case of renewable energy support schemes. *Policy Sciences*, 47(3), pp.267-287.

Department of Construction of Shandong, 2008. 关于印发《山东省可再生能源建筑应用发展规划(2008－2012)》的通知 [Notice on issuing the "Development Plan for the Application of Renewable Energy Buildings in Shandong (2008-2012)"]. Available at: http://www.fsou.com/html/text/lar/170521/17052198.html (in Chinese).

De Propris, L. and Crevoisier, O. 2011. From regional anchors to anchoring. In: Cooke, P., Asheim, B., Boschma, R., Martin, R., Schwartz, D. and Tödtling, F. eds. *Handbook of regional innovation and growth*. Cheltenham, UK: Edward Elgar, pp. 167-177.

Dezhou Daily, 2006. 我市太阳能家族添新秀 [A new member added to the solar water heater family in Dezhou]. Available at: http://www.dezhoudaily.com/folder149/folder170/folder179/2006/03/2006-03-17166522.html (in Chinese).

Dezhou Daily, 2010. 德州太阳城大会百科 [Encyclopedia of Dezhou Solar City Conference]. Available at: http://www.dezhoudaily.com/folder149/folder170/folder180/2010/02/2010-02-2110124.html (in Chinese).

Dazhong Daily, 2012. 济南企业赴英上市成功 [Enterprise from Jinan successfully listed in Britain]. Available at: http://sd.dzwww.com/jinanxinwen/201204/t20120429_7068180.htm (in Chinese).

Economy and Information Technology Commission of Shandong (Shandong EITC), 2014. 关于深化太阳能光热应用加快太阳能光热产业转型发展的指导意 [Guidelines on Accelerating the Application of the SWH System and Deepening the Transformation of the SWH Industry]. Available at: http://www.sd-solar.com.cn/policy/economy/7340.htm. (in Chinese).

Edmondson, D.L., Kern, F. and Rogge, K.S., this issue. The co-evolution of policy mixes and socio-technical systems: Towards a conceptual framework of policy mix feedback in sustainability transitions. *Research Policy*.

Essletzbichler, J., 2012. Renewable energy technology and path creation: A multi-scalar approach to energy transition in the UK. *European Planning Studies*, 20(5), pp.791-816.

Feldman, M., 2003. The locational dynamics of the US biotech industry: knowledge externalities and the anchor hypothesis. *Industry and Innovation*, 10(3), pp.311-329.

Flanagan, K., Uyarra, E. and Laranja, M., 2010. The 'policy mix'for innovation: rethinking innovation policy in a multi-level, multi-actor context. *Manchester Business School Working Paper*, Number 599. Available at: http://www.mbs.ac.uk/research/workingpapers/.

Flanagan, K., Uyarra, E., and Laranja, M., 2011. Reconceptualising the "policy mix" for innovation. *Research Policy*, 40, pp.702-713.

Gibbs, D. and O'neill, K., 2014. The green economy, sustainability transitions and transition regions: a case study of Boston. *Geografiska Annaler: Series B, Human Geography*, 96(3), pp.201-216.

Goess, S., De Jong, M. and Ravesteijn, W., 2015. What makes renewable energy successful in China? The case of the Shandong province solar water heater innovation system. *Energy Policy*, 86, pp.684-696.

Guo, Y.M., 2014. 太阳能热水器行业须坚守与创新 [The solar water heater industry need to keep innovating]. *Solar Vision*, 53, pp.20-21 (in Chinese).

Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., Smits, R.E.H.M., 2007. Functions of innovation systems: a new approach for analysing technological change. *Technological Forecasting and Social Change*, 74, pp.413-432.

Hoppmann, J., Huenteler, J. and Girod, B., 2014. Compulsive policy-making—The evolution of the German feed-in tariff system for solar photovoltaic power. *Research policy*, 43(8), pp.1422-1441.

Howlett, M., Vince, J. and Del Rio, P., 2017. Policy integration and multi-level governance: dealing with the vertical dimension of policy mix designs. *Politics and Governance*, 5(2), pp.69-78.

Hu, R.Q., Sun P.J., and Wang Z.Y., 2012. An overview of the development of solar water heater industry in China. *Energy Policy*, 51, pp.46-51.

Huang, P., Negro, S.O., Hekkert, M.P., and Bi, K., 2016. How China became a leader in solar PV: an innovation system analysis. *Renewable and Sustainable Energy Reviews*, 64, pp.777-789.

Huang, P., Broto, V. C., and Liu, Y., 2018a. From “transitions in cities” to “transitions of cities”: The diffusion and adoption of solar hot water systems in urban China. *Energy Research & Social Science*. 36, pp.156-164.

Huang, P., Broto, V.C., Liu, Y. and Ma, H., 2018b. The governance of urban energy transitions: A comparative study of solar water heating systems in two Chinese cities. *Journal of Cleaner Production*, 180, pp.222-231.

Islam, M. R., Sumathy, K., and Khan, S. U., 2013. Solar water heating systems and their market trends. *Renewable and Sustainable Energy Reviews*, 17, pp.1-25.

Jinan Daily, 2008. 我省为太阳能与建筑结合立规范 [Shandong issued standard for the integration of solar water heating systems in buildings]. Available at: http://jnrb.e23.cn/shtml/jinrb/20080124/13145.shtml (in Chinese).

Jinan Daily, 2010. 新一轮家电下乡启动 青岛力诺瑞特太阳能 [A new round of HATC was launched: Linuo Paradigma in Qingdao]. Available at: http://www.qingdao-solar.com/page_cn/article_disp.asp?id=64&sid= (in Chinese).

Jinan Xinhua News, 2009. 济南“家电下乡”发放补贴 986 万元 5 万农户受惠 [A total of 9.86 million subsidy was given to 50 thousand farmers during HATC in Jinan]. Available at: http://www.gov.cn/govweb/jrzg/2009-01/12/content_1203223.htm (in Chinese).

Kern, F. and Howlett, M., 2009. Implementing transition management as policy reforms: a case study of the Dutch energy sector. *Policy Sciences*, 42, pp.391-408.

Lanahan, L. and Feldman, M.P., 2015. Multilevel innovation policy mix: A closer look at state policies that augment the federal SBIR program. *Research Policy*, 44(7), pp.1387-1402.

Lehmann, P., 2010. *Using a Policy Mix to Combat Climate Change: An Economic Evaluation of Policies in the German Electricity Sector* (Doctoral dissertation, UFZ).

Li, J. and Qing, L., 2009. 山东太阳能热水器产业集群印象:龙头企业引领行业发展 [The solar water heater industry cluster in Shandong: Large enterprises play a leading role]. *China Appliance*, (9), pp.30-32 (in Chinese).

Li, W., Song, G., Beresford, M. and Ma, B., 2011. China's transition to green energy systems: The economics of home solar water heaters and their popularization in Dezhou city. *Energy Policy*, 39(10), pp.5909-5919.

Liu, Y.J., 2006. 首批可再生能源建筑应用示范项目名单公示 [Public notice on the first batch of demonstration projects for the application of renewable energy in buildings]. *Construction Science and Technology*, (24), pp.86 (in Chinese).

Luo and Huo, 2003. 我国太阳能热水产业的问题与对策 [Problems and countermeasures for China’s solar water heater industry]. *Solar Energy*, (2), pp.6-8 (in Chinese).

Magro, E. and Wilson, J.R., this issue. Policy-mix evaluation: Governance challenges from new place-based innovation policies. *Research Policy*.

Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: an emerging field of research and its prospects. *Research Policy*, 41, pp.955-967.

Matti, C., Consoli, D. and Uyarra, E., 2017. Multi level policy mixes and industry emergence: The case of wind energy in Spain. *Environment and Planning C: Politics and Space*, 35(4), pp.661-683.

Ministry of Industry and Information Technology (MIIT), 2013. 关于促进太阳能热水器行业健康发展的指导意见 [Guidelines for the Implementation of the Healthy Development of the SWH industry]. Available at: http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757019/c3757925/content.html. (in Chinese).

Negro, S.O., Hekkert, M.P., Smits, R.E., 2007. Explaining the failure of the Dutch innovation system for biomass digestion—a functional analysis. *Energy Policy*, 35, pp.925-938.

Qilu Evening News, 2010. 太阳能热水器三成"山东造" 太阳能白皮书发布 [One third of solar water heaters is produced in Shanong: Solar energy water paper is published]. Available at: http://money.e23.cn/content/2010-04-02/201040200278.html (in Chinese).

Reichardt, K., Negro, S.O., Rogge, K.S. and Hekkert, M.P., 2016. Analyzing interdependencies between policy mixes and technological innovation systems: The case of offshore wind in Germany. *Technological Forecasting and Social Change*, 106, pp.11-21.

Reichardt, K. and Rogge, K., 2016. How the policy mix impacts innovation: Findings from company case studies on offshore wind in Germany. *Environmental Innovation and Societal Transitions*, 18, pp.62-81.

Richardson, J., 1982. The concept of policy style. In: Richardson, J. eds. *Policy Styles in Western Europe*. London: Allen & Unwin, pp. 1-16.

Rogge, K.S. and Reichardt, K. 2016. Policy mixes for sustainability transitions: An extended concept and framework for analysis. *Research Policy*, 45, pp.1620-1635.

Schmidt, T.S., Schneider, M., Rogge, K.S., Schuetz, M.J.A., and Hoffmann, V.H., 2012. The effects of climate policy on the rate and direction of innovation: a survey of the EU ETS and the electricity sector. *Environmental Innovation and Societal Transitions*, 2, pp.23-48.

Schmidt, T.S., Huenteler, J., 2016. Anticipating industry localization effects of clean technology deployment policies in developing countries. *Global Environmental Change,* 38, pp.8-20.

Smith, A., Stirling, A., Berkhout, F., 2005. The governance of sustainable socio-technical transitions. *Research Policy*, 34, pp.1491-1510.

Smith, A., 2007. Emerging in between: The multi-level governance of renewable energy in the English regions. *Energy Policy*, 35(12), pp.6266-6280.

Solar Vision, 2011. 力诺瑞特,喜迎金色十年 [Linuo Paradigma: Welcoming the golden decade]. *Solar Vision*, (33), pp.24-26 (in Chinese).

Strambo, C., Nilsson, M. and Månsson, A., 2015. Coherent or inconsistent? Assessing energy security and climate policy interaction within the European Union. *Energy Research & Social Science*, 8, pp.1-12.

Tanner, A.N., 2014. Regional branching reconsidered: emergence of the fuel cell industry in European regions. *Economic Geography*, 90(4), pp.-427.

Trippl, M., Grillitsch, M. and Isaksen, A., 2017. Exogenous sources of regional industrial change: Attraction and absorption of non-local knowledge for new path development. *Progress in Human Geography*, 42(5), pp.687-705.

Truffer, B., Störmer, E., Maurer, M. and Ruef, A., 2010. Local strategic planning processes and sustainability transitions in infrastructure sectors. *Environmental Policy and Governance*, 20(4), pp.258-269.

Turnheim, B., Berkhout, F., Geels, F., Hof, A., McMeekin, A., Nykvist, B. and van Vuuren, D., 2015. Evaluating sustainability transitions pathways: Bridging analytical approaches to address governance challenges. *Global Environmental Change*, 35, pp.239-253.

UNFCCC, 2017. UN Climate Change Annual Report. Available at: https://unfccc.int/annualreport.

Vale, M. and Carvalho, L., 2013. Knowledge networks and processes of anchoring in Portuguese biotechnology. *Regional Studies*, 47(7), pp.1018-1033.

Wang, Y.G. and Wang, Y.H., 2010. 发展低碳绿色能源 打造太阳能产业强省 [Developing low-carbon green energy and building solar energy industry province]. *Science and Management*, (4), pp.39-41. (in Chinese)

Wang, Z., Yang, W., Qiu, F., Zhang, X., and Zhao, X., 2015. Solar water heating: From theory, application, marketing and research. *Renewable and Sustainable Energy Reviews*, 41, pp.68-84.

Weber, K. M. and Rohracher, H., 2012. Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework. *Research Policy*, 41(6), pp.1037-1047.

Weiss, W., Spörk-Dür M., and Faninger, G., 2017. Solar Heat Worldwide 2017. IEA Solar Heating & Cooling Programme. Available at: http://www.iea-shc.org/Data/Sites/1/publications/Solar-Heat-Worldwide-2017.pdf.

Yu, Z. and Gibbs, D., 2018a. Sustainability transitions and leapfrogging in latecomer cities: the development of solar thermal energy in Dezhou, China. *Regional Studies*, 52(1), pp.68-79.

Yu, Z. and Gibbs, D., 2018b. Social ties, homophily and heterophily in urban sustainability transitions: User practices and solar water heater diffusion in China. *Energy Research & Social Science*, 46, pp.236-244.

Zhao, Z.Y., Zhang, S.Y., Hubbard, B. and Yao, X., 2013. The emergence of the solar photovoltaic power industry in China. *Renewable and Sustainable Energy Reviews*, 21, pp.229-236.

Appendix

Exemplary quotes for key events in each phase

Phases	Key messages and exemplary quotes
Phase 1	**Urban-level initiatives that enable the bottom-up interaction of policy mixes** *"With regard to the mandatory installation regulation, we [Ju county] were five years ahead of the provincial regulation." (Interview, Government)* *"I remember first, it was in a regular meeting. One government official proposed the mandating of building-integrated SWH systems." (Interview, Government)* *"This [the SWH system] is required by the government. When applying for the approval of the government for real estate projects, we have to provide designs for the integration of SWH systems in buildings." (Interview, Developer)* *"Initially, the idea of building-integrated SWHs was applied in Dezhou, in one of Himin's dormitories for employees. However, this did not end up as a general mandatory policy in Dezhou. It was instead first initiated here in Ju county." (Interview, Developer)* *"Before the issuing of the mandatory regulation in Rizhao, I did fieldwork in several counties, including Ju county. I found in Ju county that at that time, the application rate of SWH systems was relatively high." (Interview, Government)* *"The mandatory installation regulation of SWH systems has been implemented in many cities in Shandong, such as Jinan." (Interview, Government)* *"Our [Rizhao's] solar energy application leads in Shandong Province, especially in the earlier years. We [Rizhao Solar Energy Industry Association], together with government officials from the Rizhao Bureau of Housing and Urban-Rural Development, went to the province [the provincial government] many times to share our experiences." (Interview, Intermediary)* *"This [Dezhou's designation of the 'Chinese Solar City'] is not only Dezhou's honour but also Shandong's honour. This has had some influence on the provincial government. At least they think that we [Shandong] got some advantages in developing the SWH industry." (Interview, Manufacturer)* **National-level policy mixes that exert top-down influences on lower-level governments** *"The subsidies for SWH installation were provided mainly by the national government. The role played by the provincial government was to facilitate implementation and supervision." (Interview, Government)* **The influence of industrial path development on the design of policy mixes** *"Dezhou is the city with the best SWH industry capacity in Shandong. Many good SWH enterprises are there, including Himin." (Interview, Developer)* *"The main reason that Dezhou was pronounced the 'Chinese Solar City' was because of the SWH industrial cluster in Dezhou. We have Himin here." (Interview, Government)*
Phase 2	**The influence of the HATC scheme on the development trajectory of the SWH industry** *"Because of the HATC scheme, the reputation of our industry has been significantly damaged." (Interview, Manufacturer)* *"For some products, to control the costs, they did not use stainless steel to produce the inner tank, and the thickness of the inner tank is only 0.22 mm. However, the inner tank thickness of our products is 0.5 mm. Just think about it…" (Interview, Manufacturer)* *"The HATC scheme was a large, nationwide strategy. It had a great influence on the development trajectory of SWH industry in Shandong." (Interview, Intermediary)* *"The intention of the national government (for HATC scheme) was good. It was just that a supervision system was not established along with the HATC scheme. Currently, the provincial*

	government was rethinking the whole policy as well. The Shandong Solar Energy Association has been calling for the establishment of the supervision institutions and the enactment of industry standards." (Interview, Manufacturer)
	Lower-level governments' complementary role under the national HATC scheme
	"At that time, there were no other policies from the provincial or urban government. Everyone was counting on the HATC scheme." (Interview, Manufacturer)
	"The national policy (HATC scheme) was passed on to the provincial government and then implemented at the local level." (Interview, Manufacturer)
	"Actually, at the local level, we normally do not issue this kind of policy [subsidies]. What we do is to implement national policies and help enterprises apply for national subsidies." (Interview, Government)
Phase 3	**Industry shakeout and concentration after policy mix reconfiguration**
	"In the past three years, many SWH enterprises went bankrupt. Small enterprises were gradually phased out, and only big enterprises remain in the industry." (Interview, Manufacturer)
	"During the HATC, there were approximately 3000 SWH enterprises in China. Now, there are only 200 enterprises. Many went bankrupt because they can no longer survive." (Interview, Manufacturer)
	"The industry concentration ratio has been increasing. In the past, there were several thousand enterprises, and now, there are only several hundred." (Interview, Intermediary)
	More complex bidirectional interactions of multilevel policy mixes
	"With regard to the SWH sector, Shandong leads in many areas in China. Policies implemented in Shandong have provided a reference for many national policies related to the SWH industry. Shandong is a role model." (Interview, Manufacturer)
	"To us [SWH manufacturers], the thing that really matters is the direction of national strategies because local [provincial and urban] policies often follow the national ones." (Interview, Manufacturer)
	"This ['Guidelines for the Implementation of the Healthy Development of the SWH industry'] should be the first guideline for the SWH industry at the national level. Therefore, the significance is unprecedented. It was not long before the provincial government enacted similar guidelines. I remember it was just one year after." (Interview, Intermediary)
	The opening up of new market segments through mandatory policy instruments
	"After the HATC scheme, the attention was back to the urban areas because of the mandatory installation in high-rise buildings in many cities in Shandong." (Interview, Intermediary)
	"The opening up of the 'construction project market' has a great deal to do with the mandatory installation regulation in high-rise buildings. This is the case not only in Rizhao but also in Shandong." (Interview, Government)

1