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Social ties, homophily and heterophily in urban sustainability transitions: User practices and solar water heater diffusion in China

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Abstract**:** This paper aims to explore the potential of latecomer cities in sustainability transitions from the demand side. The case study investigates the role of users and their social ties in influencing the popularisation of solar water heaters in a latecomer city Dezhou, in contrast to a more developed counterpart, Beijing. The two cities show vast differences in user preferences towards the low-tech environmental innovation, and the stronger social ties in Dezhou facilitate the diffusion through not only frequent social learning and peer pressure, but also enhancing user-producer trust and relation. These findings suggest that latecomer cities could provide less harsh selection environments for disruptive environmental innovations and their comparatively homogenous social ties could be harnessed to empower niche development.

Keywords**:** latecomer cities; sustainability transitions; user practices; social ties.

1. Introduction

Like the notion of sustainable development, ‘sustainability transitions’ has become a new buzzword that is being used at various sectoral and spatial levels [1]. One allure of sustainability transitions lies in its focus on the fundamental shifts of ‘meso-level’ socio-technical systems (regimes), including technologies, user practices, institutions, and cultures, as well as the relations between them [2]. The majority of sustainability transitions research studies the emergence, development, and diffusion of environmental innovations in various sectoral domains, especially in energy, transportation, and food [3]. Recently, there has been a growing interest in the geography of sustainability transitions, in terms of both conceptual frameworks and empirical studies [4–8]. The incorporation of geographical insights is believed to benefit transition studies through mapping the variances of transition activities across space and revealing the underlying processes that lead to such patterns, as well as acknowledging the importance of spatial linkages between places [9,10]. This line of research focuses on spatially embedded factors such as regional policies, natural endowments, informal institutions and industrial specialisation, in order to explain why niche development and regime transformation unfold unevenly across space [10]. Though these factors can work alone to affect transition dynamics, Gilbert and Campbell [11] argue that it is the systemic combination and interconnected structure of regional configuration, rather than the simple collection of these factors, that give rise to radical technological regime changes.

While the mainstream transitions literature predominantly focuses on transitions at the national scale [3], the geography of transitions literature pays more attention to the role of cities and regions [12–15]. Nonetheless, most empirical focus has been upon sustainability transitions in developed western cities, while the role of smaller cities and less developed cities in the global south has been neglected [16]. Less developed cities are yet to experience deep industrialisation and urbanisation (hence, latecomer cities), and their transitions to sustainability from the outset could have a very significant impact on mitigating global climate change. Under the prevailing global landscape of green development, these latecomer cities may have much potential in sustainability transitions as they are less locked-in by incumbent unsustainable regimes and thus provide favourable niche spaces for experiments with sustainable technologies and new governance forms [17]. It is thus of pivotal significance to explore the endowments of latecomer cities in pursuing sustainability transitions.

One of the advantages of latecomer cities in sustainability transitions may rest on user practices and social ties. Transition analysis so far has a strong bias towards the production side, while demand-side factors are less studied [18,19]. Many transition studies presume that environmental innovations would not be valued by the market itself, but rather mainly rely on regulatory pull and technology push to get promoted. However, due to economic, social and cultural differences, users in different places may have very diverse attitudes towards the same green innovations. Consumer preference may offer an indication of direction which, if given sufficient agency, may result in a transition from one type to another [20]. Furthermore, the diffusion of innovations is not solely determined by the desirability of the products, but also affected by the diffusion channels and networks among users [21]. Users should not be merely considered as rational agents, rather, they are also governed by social structures, or “ the patterned arrangements of the units in a system, which gives stability and regularity to individual behaviour in a system” [21](p.37).

One possible reason why users in transition research have been overlooked is that most studies focus on high-tech innovations where ordinary users have little part to play in their technology development [22]. High-tech innovations are undoubtedly important for low-carbon development,

but comparatively cheaper, 'good enough', low-tech innovations are also of global significance in transitioning to the green economy [23]. These innovations are usually low-cost and low-tech products targeting previously excluded markets, but they possess considerable potential to grow their markets and may eventually come to dominate. Such innovations are not only more affordable, and thus available to the bulk of the world's population, but also could be 'disruptive' by redefining technologies and setting novel development paths [24]. Thus, low-carbon disruptive innovations could be of much greater and more direct relevance to sustainability transitions in countries such as China [25]. Latecomer cities may enjoy a better position in such transitions because they usually face less resistance from incumbent technologies and have greater preferences for inexpensive low-carbon innovations.

This paper aims to fill these research gaps by exploring the diffusion of low-carbon disruptive innovations in latecomer cities from the demand side, with a focus on user practices and social ties. We believe user practices in latecomer cities could provide a less harsh selection environment for such transitions. Moreover, their social ties are expected to be stronger and thus facilitate niche development. To test these ideas, this paper provides a contrasting case study of the popularisation of solar water heaters (SWHs) in two Chinese cities, Dezhou and Beijing. China has been the world's leading country in utilising solar thermal energy, accounting for approximately 80% of global production and 71% of global installed capacity in 2015 [26]. SWHs have been particularly widely popularised in China's rural areas and small cities [27]. Dezhou is a latecomer in industrialisation and urbanisation, but has an SWH cluster of national importance and a high popularisation rate of SWH [28]. It has been designated as China's Solar City and received wide international environmental recognition. Beijing is much more developed and has one of China's biggest SWH cluster. Nonetheless, the market penetration of SWH is much lower - in Beijing's urban area, the SWH installation rate was less than 7% in 2009. Previous research has argued that the popularization of SWH in Dezhou is a combined result of weak regime resistance and strong niche development with a positive feedback loop between powerful SWH firms, supportive local government, motivated estate developers, and networked users [17]. This paper attempts to contribute to the literature with a more in-depth analysis of the role of users and social ties in Dezhou's transition to SWH.

The paper is structured as follows. Section 2 introduces the theoretical background of users and social ties in the diffusion of innovations, where we propose that strong social ties could be an underestimated endowment for latecomer cities' sustainability transitions. Section 3 describes the case study cities and methods, and Section 4 provides the result of Dezhou in contrast to Beijing. Theoretical implications are discussed in Section 5 and the final section concludes the paper with policy implications to harness social ties to facilitate latecomer cities' sustainability transitions.

2. Theoretical background

A number of studies have provided much understanding about what drives environmental innovations [29,30]. These factors are divided into either internal factors and external factors at the firm level [29], or technology push, market pull and regulatory push factors at the sectoral level [31]. As most environmental innovations have a lower price/performance ratio than conventional alternatives, they are often subject to a vicious circle: consumers have little faith in them because of their technological problems such as high cost and incompatibility, while producers blame the high cost on the lack of scale economies due to uncertain market demand. Therefore, policy intervention and technology push are believed to be essential for the realization of environmental innovations in the early stages [31,32]. This is particularly true for expensive high-tech innovations such as PV and wind turbines, whose deployments have mainly been driven by subsidies and technology development.

Demand factors are perhaps the most challenging selection environment for new innovations. Consumer preference for existing technologies has been the consequence of the co-evolution of supply side, relevant institutions, and infrastructures, as well as cultural factors. The criteria to adopt certain innovations have been shaped by the existing infrastructures and products in the market, and established use habits constitute an immediate obstacle for new technologies to overcome. The challenge of sustainability transitions thus lies not only in the long-term change of technologies and infrastructures, but also in ensuring that consumer criteria change at the same time [33].

Users have usually been seen as the end point of a diffusion process and their role is mainly reflected in their purchasing power. Research studying the adoption of SWH, for instance, usually investigates the personal preference of individual consumers, concluding that economic savings and environmental awareness are the main driving forces, while financial cost is the primary barrier [34–36]. This, however, largely overlooks many important processes of diffusion other than purchasing. Rogers' [21] innovation diffusion theory argues that when users adopt an innovation this is not simply due to impulse decisions, but as a result of a sequential stages of actions, including knowledge (i.e. being aware of the existence of an innovation), persuasion (i.e. forming an attitude toward the innovation), decision (i.e. deciding to adopt or reject an innovation), implementation (i.e. putting the innovation into use) and confirmation (i.e. seeking reinforcement of the already made innovation-decisions). This raises a number of questions - how do potential users obtain the knowledge of a particular innovation? What contributes to forming attitudes toward an innovation? And does peer behaviour matter in decision making? These questions are related to social structure and networks through which social learning of an innovation occurs.

Depending on how relatively early an individual is in adopting new innovations than the other members of a social system, innovation adopters are categorised into five types: innovators, early adopters, early majority, late majority, and laggards [21]. There have been found many differences among these categories in terms of factors such as socioeconomic status, personality characteristics, and communication behaviour. Generally, earlier adopters are financially better off, have more education and higher social status; they are more open-minded and have a more favourable attitude toward change; they are more actively engaged with their information channels and more influential in their interpersonal networks. Evidently, these adopter groups follow different logics that cannot simply be assigned to economic rationalities. While some groups are more motivated by efficiency criteria, others might just follow pioneers due to the bandwagon effect to maintain social desirability [37].

How social structure and networks work in the diffusion of innovations relates to two concepts, homophily and heterophily [21]. Homophily refers to the similarity between individuals in a social system in certain attributes, such as occupation, education and beliefs. A generalisation proposed by Rogers [21](p.305) is: "exchange of ideas occurs most frequently among the individuals who are alike, or homophilous". This is because communication between those who are alike is usually more effective as they share common meanings and mutual understanding [38]. Also, social learning, in turn, enhances homophily [37]. On the contrary, communication between people with marked differences (heterophily) could be less effective due to the knowledge, cognitive and psychological distances.

Social ties theory has argued that weak social ties help individuals being exposed to more information and opportunities [39,40], and thus, facilitate diffusion of innovations to different social groups and distantly located places [41,42]. However, while weak social ties may be

important at the macro level to bridge distinct subgroups in the broader social system, strong and homophilous ties are more critical for the flow of referral information at the micro level [43]. Information and influence are the two underlying dimensions of social ties [44]. The strength of weak ties has been widely proved in getting access to information that cannot be obtained from close interpersonal networks. But when it comes to the influence dimension, strong social ties are believed to be more advantageous in accessing influence, which is generally more costly and difficult to achieve [45]. Strong ties could not only enhance the trust among social members on the pull side but also increase the peer pressure on members who have not adopted the innovation on the push side. As Ruef [44](p.430) states: "strong ties impose greater demands for conformity on a focal actor. Family members and friends who are consulted regarding new business ideas may be insulted when other elements are introduced that deviate from or clash with their own way of doing things". Within a specific social group, strong social ties could be more influential in diffusing an innovation to a larger number of social members.

Strong social ties not only work among consumers in adopting products by reducing uncertainty [46], but could also enhance user-producer relationships. Users cannot simply be viewed as the passive agent in adopting technologies, but as active players that co-evolve with producers [47]. The co-development of the user-producer relationship could transform a product from a fixed and frozen thing "into a state within an iterative, never-ending process of experiment, negotiation, modification, and so on" [47](p.272). Applying the technological innovation system (TIS) approach, Randelli and Rocchi [22] show that the involvement of consumers in alternative food networks can not only strengthen the innovation process, but also "positively influence the social legitimacy of an innovation, mobilize local resources, and affect the process of creation and dissemination of knowledge, as well as support market formation"(p.103). However, relational proximity has been less studied compared to physical proximity in approaches that acknowledge users' role in innovation process [47]. Though geographical proximity is believed to stimulate learning between users and producers, social proximity appears primarily important in relation to trust building between them [48,49]. Social proximity based on kinship, friendship, and mutual experience could provide a higher level of trust that is conducive to niche experimentation. Close interpersonal networks at the local level can play an important role in the diffusion of market and technology information, which are essential to the formation of industry clusters [50].

Therefore, it has been suggested that there should be a focus on the community level rather than the individual level in sustainability transitions, so that the social capital and trust in the community could be taken advantage of [51]. Moreover, when a transition discourse becomes dominant in the community, a sense of place identity is enhanced, which in turn reinforces the mobilisation of more resources and participation [52]. As Aylett [51](p.869) states in the example of Solarize Portland:

> By changing the scale of action from the individual to the community, Solarize accomplished two things: it was able to use social ties to build demand for technological change, and simultaneously to use technological change to reinforce and expand those ties through a shared sense of accomplishment that community members could point to with pride.

Therefore, leveraging social networks could be a cost-effective way to promote the adoption of environmental innovations [46,53,54]. For example, Liu et al., [55] investigated China's rural public acceptance of clean energy and found the majority of respondents would be very likely to take the same energy options as their neighbours who share similar lifestyles and cultural connections. We contend that homophilous social structures and strong social ties could be a more prominent feature in latecomer cities where urbanisation and industrialisation have yet to

unfold. Granovetter [40] has argued that the most important source of weak social ties is the division of labour, because "increasing specialisation and interdependence result in a wide variety of specialized role relationships in which one knows only a small segment of the other's personality" (p. 203). Latecomer cities are usually in the transition from rural societies to urban societies with a limited division of labour in contrast to developed cities. Their social systems are more characterised by homophily in socioeconomic status and cognitive attitude. Kinship-based social relations are more easily found in less developed regions [52], and latecomer cities could harness them to promote certain environmental innovations, on the precondition of formal legal rules.

In specific to the SWH diffusion in Dezhou and Beijing, this paper tries to address the following research questions: a) How different are user practices regarding SWH adoption in the two cities and to what extent do these differences explain the diffusion outcome? b) What is the role of social ties in affecting SWH diffusion? c) Under which conditions can user practices and social ties be an advantage for latecomer cities' sustainability transitions?

3. Methods

3.1. Case study cities

This research involves a contrasting case study of the diffusion of SWH in two Chinese cities, Dezhou and Beijing. Dezhou was traditionally an important agricultural city in China. It was not until 1995 that the dominant role of the agricultural sector in Dezhou's economy was replaced by secondary industry. In 2014, Dezhou's GDP per capita reached US$ 7080, just below the national average, but 30% less than the Shandong provincial average and only a half of the level of Beijing. Accompanying this, Dezhou's urban population reached 2.6 million, raising the urbanisation rate[1] from 30.5% in 2000 to 46.24% in 2012. This level is still 6.19% less than the national average level (Figure 1). According to Dezhou's census system, 4 million of the population belongs to the agricultural population and only 1.77 million are non-agricultural [56]. In contrast, Beijing is one of the most developed cities in China. In 2013, Beijing's GDP per capita had reached US$ 15051. If measured by the UN Food and Agriculture Organization's standard, Beijing has become a wealthy city. The city's population has grown significantly at an average rate of 2.5%, reaching 21.5 million in 2014 and 86.3% of the population live in its urban areas.

[1] Urbanization rate= urban population/ total population. In China's case, urban population refers to the population that stay in the urban areas more than six months a year.

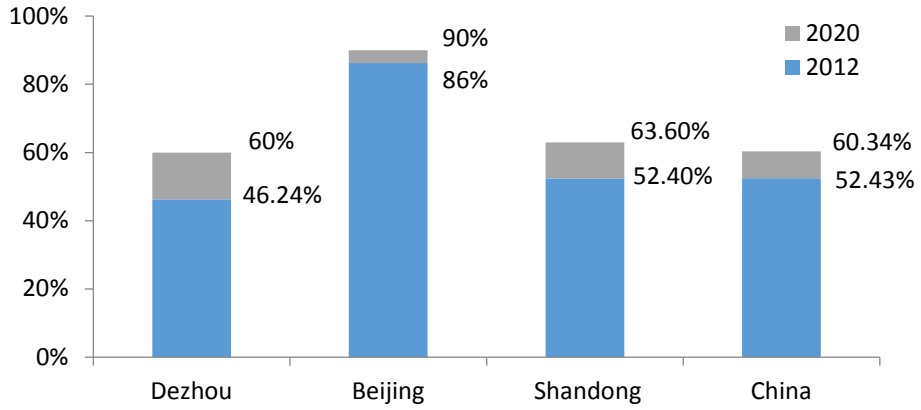

Figure 1. Dezhou, Beijing, Shandong and China's urbanisation rate in 2012 and 2020 vision

Source: Edited from Dezhou Urban Master Planning 2011-2020, Beijing Urban Master Planning 2004-2020, Shandong Urbanization Development Outline 2012-2020 and China Small and Medium City Green Book, 2013.

A contrasting study aims for greater explanation of one case through using other cases as a reference point. Dezhou is a latecomer in industrialisation and urbanisation, but it has become the pioneer in SWH utilisation. Admittedly, with such a huge socio-economic gap between Dezhou and Beijing, a direct comparison between them regarding particular social phenomena might be inappropriate. But if researchers wish to understand the socio-technical factors in latecomer cities in more depth, a contrasting knowledge of a more developed counterpart is not only helpful but necessary. Without understanding what is going on in the more developed cities, the factors that matter in latecomer cities' context would not be interpreted as being significant as it should have been. In this research, the main focus of inquiry is on the diffusion of SWH in Dezhou, but Beijing's story is also narrated to illustrate the significance of certain socio-technical factors in latecomer cities' context.

Moreover, despite the vast socio-economic differences, the contrast between Dezhou and Beijing regarding SWH diffusion is warranted because both of them are the main SWH manufacturing clusters in China and both municipal governments encourage and mandate SWH installation in their urban areas, though at different times. But there is a huge adoption gap of this technology between the two cities due to place-specific, socio-technical factors. A contrasting study of these two cities helps to reveal how geographical contexts matter in the diffusion of SWH in each city and illustrates the role of users and social ties in latecomer cities' sustainability transitions.

3.2. Data

It is understandable that most research on user preferences adopts surveys to investigate individual characteristics and economic choices, but it is surprising that research on the social networks has been primarily dominated by model simulation [38,57–59]. There are very few studies based on real-world observations. A survey usually only explores users' individual preferences and behaviours, and institutional and cultural contexts are often neglected. This study instead presents the findings regarding the role of users and social ties from interviews and site observations. Between November 2014 and February 2015, 36 semi-structured interviews were conducted with SWH entrepreneurs, industry associations, research institutes, government officials, and estate developers in Shandong (mainly in Dezhou) and Beijing, in order to

investigate the facilitating and obstructing factors of SWH diffusion, among which, user preferences and social structure were key topics. We believe these interviews, especially those with SWH entrepreneurs and marketing managers who have been continuously engaged with consumers, are able to provide very valuable and complementary knowledge to surveys only focusing on individual preferences. Questions in the interviews mainly focused on which factors facilitate or obstruct SWH diffusion in the case cities, and user demand is one of the key topics. These interviews were complemented by document analysis and site observations in the two case cities, including many unstructured interviews with SWH users, house owners, letting agents and other urban residents. Site-observation is of great value in investigating a social structure by spending a period of time being, working or living in a community in order to discover the functioning of the system [60]. It allows researchers to get as close to the research site as possible and gain first-hand knowledge of what actually happens in the system. Researchers' direct experience in the socio-temporal context enables them to reach an in-depth understanding of the particular place.

4. User practices and social ties in Beijing's and Dezhou's SWH diffusion

4.1 Dezhou

Dezhou's solar industry dates back to 1995 when the Himin Group was established, which soon became the largest SWH manufacturer in the world. Himin made great efforts in popularising knowledge about solar energy, both in Dezhou and nationally. The market developed by, and technology spillovers from, Himin stimulated further local entrepreneurship in Dezhou's solar industry. In 2005, Dezhou government officially carried out the *Solar City Strategy* and a series of preferential policies and plans were implemented to provide comprehensive support to the solar industry. In 2010, the city was home to more than 120 enterprises engaging in solar-related industries, It sells a total of 26 million square meters of SWH, representing approximately 70% of Shandong's and 16% of China's capacity respectively. There is a wide application of solar energy in Dezhou, with an installation rate of SWH among the highest in China and an international recognition as 'China's solar city'. The SWH industry, especially the largest firm Himin, and local government have played very pivotal roles in Dezhou's popularisation of SWHs [17,28].

The story would not have been complete without the driving force from the demand side. Before the popularisation of home-use water heaters, residents in northern China generally bathed less often than in southern China due to geographical conditions (e.g. dry climate and water scarcity) and cultural traditions (interviews 1,4,6,10). The situation was similar in Dezhou, as a typical northern city. Though electric water heaters (EWH) and gas water heaters (GWH) were used before SWH in the 1990s, they were not well popularised because they were deemed as a kind of luxury lifestyle which most residents were not able to afford. Nonetheless, the presence of home-use water heaters introduced residents to a more modernised bathing fashion. This demand was met by the less costly SWH. Though the initial cost of SWH is generally higher than EWH or GWH, it hardly involves any further energy cost in use.

In the early 1990s, the earliest adopters of Himin's SWH were the relatives of the entrepreneurs and residents with higher education levels, such as teachers and doctors, which led to a demonstration effect for other residents (interviews 1, 3). As SWH technology matured, an increasing number of residents chose to install SWH on their roofs because it saved on their energy bill. According to the survey by Li, et al., [28], the average payback period of an SWH for a typical three-person household in Dezhou is 8.3 years, allowing for 4 years free use of its designed life expectancy. Although most SWHs were not able to work as effectively as EWHs or

GWHs in winter, local residents view SWHs as convenient, economical and safe products that have improved their living standard. As a senior manager said:

> In the past, in order to save coal or gas in winter, people use cold water to wash face. Children cried when they had to wash their face because the water was so freezing. Now…when they do laundry or wash dishes, they can also use the hot water from SWH, at least, it cost almost nothing to use. SWH does improve people's living quality [interviewee 1].

Considering its economic merits, local residents show high tolerance to SWH's technical problems such as poor performances in undesirable weather conditions and water waste due to long transporting pipes from rooftops. Many users have adapted their daily practices for the best performances of SWHs, but they barely view them as inconvenient.

Admittedly, there was a portion of residents who chose to install SWH out of environmental awareness, but the majority of adopters accepted SWH because of its economic savings and 'good enough' performances. As an entrepreneur put it:

> Ordinary people do not care about this [emission mitigation], they think it is far away from their life… What they care is that SWH can guarantee their bathing needs and save on energy bill…Ordinary people just need tangible benefits, rather than high-profile slogan [interviewee 4].

Besides the economic rationale of individual households, the close interpersonal networks among local residents in Dezhou are also an indispensable part of the diffusion. Fei [61] argued that close interpersonal networks or 'guanxi' is a distinct characteristic of China's rural society. This characteristic may be decreasing, but is still evident in small latecomer cities when compared to large developed cities in China. Unlike Beijing and other big cities, where urbanisation is primarily driven by immigrants from various regions of the country, Dezhou's urbanisation is mainly a consequence of the transformation of local rural residents into urban residents. Therefore, their kinship, friendships and neighbourhood relations remain an obvious characteristic, and the verbal communication and social learning of SWH acceptance among acquaintances can be easily observed.

At the initial stage of the diffusion, when solar energy was hardly known to mass consumers, Himin's founder started exploring potential markets by presenting SWH to his friends and relatives as gifts to see how they worked. Among Dezhou's first group of SWH adopters were many SWH entrepreneurs' relatives, who bought SWH just to do the entrepreneurs a favour, but turned out to find the products useful and convenient, and the merits of SWH were proliferated among neighbourhoods (interview 3). Many relatives and friends adopted the innovation because of trust and kinship relations, rather than because they were financially better off and more open-minded to innovations. SWH also began to gain increasing legitimacy among local residents when the local government implemented the Solar City Strategy and the city was known as China's Solar City. With the retail SWH market growing quickly, some estate developers began to incorporate SWH into their residential developments to attract house buyers. It then became a mandatory requirement for estate developers to install SWH collectively on their buildings due to local government's mandatory installation policy. Though a growing number of residents, especially young people, begin to install EWHs and GWHs as they become richer, the general residential building structure has favoured SWH incorporation. By 2014, 95 percent of new residential buildings in Dezhou's central urban area had been incorporated with SWH systems.

With the huge promotional efforts from SWH industry and local government, as well as increasing national and international recognition through media reports, building 'China's Solar City' has been a prevailing social discourse among Dehzou's residents, who are proud of this new city image and gradually built it into a new place identity. Consequently, conforming to the social expectation and participation in green activities also contributes to Dezhou residents' adaptive attitude towards SWH [28].

Peer comparisons often happen in acquaintance neighbourhoods and thus also contribute to SWH diffusion. The culture of 'face' is not unique in Dezhou, rather, it is common in China's acquaintance society, especially in rural areas. The desire of not lagging behind acquaintances is believed to be an important factor that has driven the diffusion of many household appliances in China, such as TVs, refrigerators and telephones. The same social psychology applies to the diffusion of SWH in Dezhou and in many less developed regions of China. As an entrepreneur gives as an example:

> In a village with one or two hundred households, as long as one of them installs SWH, the rest of the community will follow..., whoever hasn't had SWH on his rooftop feels losing face to the neighbourhood. The performance of SWH is merely one side, the other side is whether this product satisfies people's social vanity… [interviewee 4].

Thus, the strong social ties in this social system not only facilitates information flow of SWH on the pull side, but also exerts a pressure on potential adopters to follow on the push side. In such an acquaintance society, strong interpersonal networks exist not only amongst consumers, but also between users and producers, as well as amongst producers. As the industry grew in the local economy, a big portion of the local residents was involved with the supply side both directly and indirectly as employees, sale agents and the like. It is reported that around one-third of the city's workforce is employed in the solar-related industry [62]. With many acquaintances working in the SWH industry, local residents were more frequently exposed to SWH information and thus obtained more knowledge of the technology. This also enhances the trust-based communication between consumers and producers of SWHs. As a marketing manager illustrated:

> We have a big SWH industry here, and many people work for the industry, naturally, they know the benefits of SWHs [interviewee 2].

Furthermore, many of Dezhou's SWH firms were established or spun-off with help from relatives and friends who were already operating businesses in the industry. Close interpersonal networks have also exerted much influence on local entrepreneurship. This is illustrated by an SWH entrepreneur:

> I didn't think too much before entering this industry, because my family members were doing SWH business, I followed them and made casting equipment for Himin at first…[interviewee 4].

Evidently, the strong social ties in Dezhou have played a significant role in the diffusion of the market and the formation of an SWH industry cluster.

4.2 Beijing

Like other big cities in China, Beijing is confronted with common urban problems such as traffic congestion, water contamination, air pollution and waste pollution, but the biggest environmental problem in recent years is air pollution. The municipal government has exhibited great enthusiasm in addressing pollution through renewable energy development. Beijing is the

birthplace of China's solar thermal industry. In particular, Beijing Solar Energy Research Institute and Tsinghua University have played a critical role in the development of China's flat-plate and evacuated tube collector technology. It has one of the main SWH clusters in China, with a strong capacity in research and development. Beijing's SWH industry grew with an increasing number of SWH firms being established due to this technology advantage, but there are also many firms established in Beijing to utilise Beijing's 'city brand' to promote marketing (interviews 33, 34). Regarding application, most of the SWH application only occurs in Beijing's suburban-rural area, where the demand conditions and social ties are, to some extant, comparable to Dezhou's, while the much more populated urban area is a harsh environment for SWH diffusion.

Residential building infrastructure is one of the main barriers to SWH diffusion mentioned by many interviewees (interviews 10, 12 28, 33, 35). Generally, the older and the higher a residential house is, the less likely it would be to install a solar system [35]. By the time the SWH industry started growing in China, Beijing's built urban area had been largely covered with dense high-rise buildings. Due to the booming population and increasingly scarce land resource, residential buildings in Beijing are not only densely built but also make full use of their vertical aspect, resulting in a high land use intensity. This building infrastructure impedes the installation of SWH even if residents wish to do so. For evacuated tube SWHs, there is not sufficient space on the rooftop of high-rise buildings for solar collectors. Also, the long transportation of hot water to lower floors would induce substantial energy loss. Flat-plate SWHs are believed to have more advantages being incorporated into high-rise buildings, but they also have problems in fitting with Beijing's residential building structure.

Low energy costs and higher income levels together make renewable energy less attractive for urban residents in Beijing. Rather, comfort, safety, aesthetics and status symbols are the priorities when purchasing household appliances. SWH has long been viewed as a low-end product due to technology weakness. This is more evident in Beijing because it was unable to satisfy wealthy urban residents' high-end demand. Even though the SWH industry has made great improvements in technology innovation, the vicious competition between SWH enterprises results in a poor reputation for SWH [63]. Consequently, few urban residents have much knowledge of SWH. Instead, they tend to purchase EWHs and GWHs which they believe to provide a better performance than SWH for reasons of convenience, safety and aesthetics.

> Beijing's residents are getting rich, coal and electricity could be easily afforded. SWH, at its best, is not as reliable as primary energy, right? It depends on weather and thus is not stable. But EWH is much more convenient, you can use it as soon as you turn it on [interviewee 32].

As many interviewees suggested, residents in wealthy regions are more likely to be driven by environmental awareness in using environmental technologies. Beijing's residents are generally believed to have a higher level of environmental awareness in China. In particular, the 2008 Beijing Olympic Games has been a strong push factor in improving residents' attitudes towards environmental protection. In recent years, air pollution has been one of the top concerns in residents' daily life. Indeed, besides government's environmental measures, many civil environmental movements have been initiated. However, when it comes to small technologies like SWH, people tend to not pay enough attention to its role in reducing pollution. As one interviewee put it:

> It is very unlikely that people would notice that this single product could make a difference, at least, not in a direct way. When mentioning haze, they think of manufacturing factories or automobiles, the two largest pollution sources. How

> could they relate using EWH or GWH at home with air pollution? They are sure not to think so [interviewee 28].

In fact, solar thermal energy is playing a significant role in reducing emissions, but this is not well known to citizens. Some interviewees believed that citizens still haven't taken many individual efforts to counter environmental problems, even if they understand the role of daily life changes in improving the environment. Between a tiny improvement to the public environment and an instantly comfortable lifestyle, most of the people would lean towards the latter.

> …but few people would take real individual measures to counter pollution as they think it is government's responsibility to make the sky blue [interviewee 32].

In short, neither economic savings nor environmental awareness provides sufficient motivation for Beijing's individual residents to use SWH. Estate developers thus do not have the incentive to integrate SWH into buildings. Though there are some large estate enterprises who actively incorporate SWH into their building to establish a green image and to differentiate them from their competitors, the majority of estate developers do not bother with SWH-building integration (interviews 27, 30, 32). Due to lack of trust in the quality of SWH, estate developers tend to regard SWH incorporation as a burden rather than a market opportunity.

Even when residents had the desire to install SWH, many property managers did not allow the installation on aesthetic and safety grounds. Sometimes, residents may have installed SWHs secretly, but estate management would take them down eventually (interviewee 28). As another interviewee suggests, residents do not have much discursive power over property management (interviewee 27).

> Sometimes, it just likes cat-mouse game between residents and property management. Even if residents really wish to use SWH, property management just stand in the way [interviewee 33].

A general observation in Beijing is that it obviously has a very heterogeneous social system in contrast to Dezhou. As a modernised international city pulling in millions of immigrants from different regions of China, Beijing is a city of high social varieties in occupations, educations, incomes, beliefs and other socio-economic characteristics, and the gap between the social members could be extremely wide. These heterophilous social ties render very infrequent interpersonal communication between residents, not to mention the information flow of household appliances. In addition, though Beijing has one of the largest SWH clusters in China, most of its enterprises primarily target markets outside of Beijing's territory. This means the SWH cluster in Beijing is disengaged with local consumers, resulting in very limited user-producer communications in SWH diffusion.

5. Discussion

As demonstrated, user practices are not only about individual rational preferences, but also shaped by physical infrastructure, incumbent technologies, cultural factors and social structures, all of which have very different purchases in cities at different development stages, posing various regime resistances to new innovations. The unprecedented urbanisation in China is not only about hundreds of millions of the population moving to cities, but also means enormous urban physical landscape changes in the transport system, energy supply, and building

infrastructure etc. to accommodate its growing population and economic activities. As Furlong [64] argues, it is problematic to view infrastructure simply as a 'black-box' with little interaction from users. Rigid urban infrastructure conditions urban actors' behaviour and the possible options to change the practices [65]. As urban physical infrastructure is increasingly taken for granted, the established rules, behaviours, cognitions, and artefacts attached to it also gain more legitimacy, forming further obstacles for new innovations.

By contrast, as a latecomer in urbanisation, Dezhou's residential buildings are principally low-rise ones, providing considerable available space for SWH installation. This market inertia continues in the high-rise buildings market because the government's mandatory installation policy was implemented at the same time as the emergence of high-rise buildings in Dezhou. Similarly, Tyfield *et al.*,[66] find that the tightly packed building infrastructure in China's populated megacities represents a barrier to EV adoption, because few residents have private garages for charging, whereas certain rural areas have demonstrated a promising niche market for cheaper and low standard EVs. Späth and Rohracher [52] also show that the transition to biomass energy in Murua, Austria, is much related to its small and dispersed population and limited industry, which makes the region 'off the radar' of the national gas grid, therefore, helping to form a discursive niche due to less resistance from incumbent energy infrastructure. The latecomers in urbanisation generally have not been dominated by particular physical forms and this leaves room for the uptake of new environmental innovations.

Also, the early dominance of GWH and EWH in Beijing renders few of its urban residents having awareness or knowledge of SWH, not to mention its relative advantages. If the relative advantages of new innovations have not been identified by consumers, it is unlikely that they will be adopted [34]. Even when SWH's relative advantages in energy saving and their environmentally benign outcomes are recognised, they are not so attractive to Beijing's urban residents whose purchasing criteria have been biased towards convenience, safety, aesthetics and comfort, and since their domestic energy bill only accounts for a small portion of their incomes, they do not have much incentive in saving energy bills. As interviewees suggested, consumers in developed regions have higher requirements on product functions and performances. This forms a harsh selection environment for environmental innovations which usually cannot compete with established technologies in overall performance. Indeed, residents in developed regions are more able to afford the higher cost of new innovations, but more capacity does not guarantee more willingness. Moreover, individual consumption practices have been an increasingly significant indication of individual freedom and social status of China's rising middle class, hence, "consumerism is of heightened social and political significance" [66](p.29). The pursuit of this social identity through individual consumption usually leads to the aspiration for expensive and advanced products, which further marginalises low-tech innovations such as SWHs.

Environmental awareness has been an important driver of the diffusion of many renewable energy technologies, but it has different purchase in different places [67]. Environmental pressures have driven many local authorities to popularise renewable energy technologies, but they seem not to have been taken seriously enough by individual social members to take environmental actions in developing China, even in its first-tier cities. China's middle class still considers environmental quality an issue of lower priority than many themes such as children's education, health and housing [68]. Due to the lack of knowledge about SWH, residents also doubt how such a small domestic appliance could make a difference to environmental improvement. On the other hand, even if they realise the significance of this environmental technology in achieving a greener environment, their awareness is still not imperative enough to drive them to sacrifice their individual comfortable lifestyle for collective environmental benefits. There is still a gap between environmental consciousness and genuine actions.

The primary market selection criteria of water heaters in Dezhou has always been about economic savings, which is the primary relative advantage that an SWH can provide over its substitutes. Compared to economic savings, other criteria such as convenience, comfort and aesthetics are not prioritised, leaving much room for SWH growth at the initial stage. This high tolerance to the technical problems associated with SWH is also seen in other small cities such as Rizhao, where most residents have taken the inconveniences for granted and adjusted their practices to the expected performance of SWHs [69]. Given the growing individual market, Dezhou's estate developers also changed their attitudes from hostility to embracing the technology. Overall, the regime resistances from user practices in Dezhou are much weaker and even welcome the new technology. Being a latecomer in economic development means having different selection criteria from developed regions, and if the new green technology is able to meet its principal criteria (e.g. economic saving), it is very likely that a wide adoption will follow.

What also matters are the place-specific social structures and interpersonal networks. The diffusion of SWH in Dezhou has displayed different adopter categories showing different adopting rationalities. The SWH entrepreneurs were typical innovators. They learned the idea of solar thermal energy and brought the knowledge from the cosmopolitan level to the local. The major early adopters of the technology were those with higher socio-economic status in Dezhou such as teachers and doctors. They were respected and trusted in local society and their adoption led to a role model effect. However, there was also a portion of early adopters who were the relatives and friends of the SWH entrepreneurs. They did not necessarily play the role of opinion leadership, but were able to facilitate the diffusion through their own interpersonal networks. The subsequent diffusion of SWH had much to do with its economic benefits, but the close interpersonal networks of local society also played a critical role.

The notion of homophily and heterophily provide useful insights to understand the difference of SWH diffusion between Dezhou and Beijing. It seems that a city's social variety (heterophily) grows with its economic development. Generally speaking, the more economically advanced a city is, the higher social variety it has [70]. Latecomer cities are usually constrained to limited industries, their social systems are more characterised as homophily in socio-economic status and cognitive attitude. Dezhou was such a city with a rather homophilous social system. The social learning of SWH installation through observation and communication happens more frequently and effectively due to social members' similar socio-economic conditions. More importantly, it seems that a social discourse (e.g. solar city or green development) is more likely to prevail in a homophilous social system once it is built into a place identity, giving more legitimacy to the adoption behaviour of green products.

Nonetheless, the notion of homophily only describes the similarity within an interpersonal network, not the strength. Homophily increases the probability of communication, but not necessarily the trust between social members, which may be more critical in social learning. Peer behaviour is an important trigger of diffusion [37], but peer behaviour from strangers may not bring as much influence as that from acquaintances who know and trust each other. Researchers emphasise the co-location of users and suppliers in local market formation, especially in the early phases because spatial proximity enhances interaction and mutual learning [71]. However, judging from our observations in Dezhou and Beijing, the co-location of producers and potential users does not necessarily lead to close interaction between them. What makes a difference in Dezhou's case, however, is the close social ties between producers and local residents in the early development stage.

Also, the fear of 'losing face' to peer communities has been an evident driver of SWH diffusion in China's rural society. The social structure of China's traditional rural society is based on kinship relations or guanxi networks, in which individuals build social networks along their own kinship ties with themselves locating the centre, resembling "the cycles that appear on the surface of a lake when a rock is thrown into it" [61](p.60). Guanxi in Chinese society is a typical strong social tie characterised by the familiarity of intimacy, trust worthiness, and reciprocal obligation [72]. Guanxi networks facilitate the exchange of intangible or tangible favours. As society modernises, kinship relation is increasingly challenged by formal market rules and legal configurations [73,74]. The more modern a society is the fewer kinship relations in place [75,76]. Guanxi relations are also believed to be declining in China's transition to an urban industrial economy [73]. However, the kinship relations within latecomer cities may have declined but could still remain a prominent feature when compared to modernised cities.

It is not uncommon to see guanxi being viewed as a negative thing as it often relates to backwardness, informality, non-transparency, corruption and using social rules to interrupt market competition [73,77,78]. The exchange feature of guanxi does leave much room for unauthorised or illegal practice. Indeed, many SWH entrepreneurs complained that inferior SWHs drive out the good SWH firms, because guanxi, rather than performance, is the primary factor for SWH firms in winning SWH-building incorporation projects from estate developers [63]. However, the original value of guanxi in interpersonal intimacy and trust could be brought back to facilitate the diffusion of environmental innovations. Since environmental technologies are not mature enough from a purely technological perspective, relying merely on market rules to diffuse them may not be sufficient, especially in modernised urban areas. Strong social ties, in this case, demonstrate several advantageous aspects in popularising certain environmental innovations for public well-being. In terms of the policy implications, there has been much work studying the role of demand policies, such as mandates, subsidies and taxes, in promoting the adoption of environmental innovations, but little attention has been paid to the role of place-based identity and personal networks. Given that latecomer cities generally lack of resources to invest in the full suite of demand policies, place-based identity and personal networks may have a bigger role to play in latecomer cities' demand policies.

6. Conclusions

In this paper, we have demonstrated that the SWH, as a typical disruptive environmental innovation, has very different popularity in two cities at different development stages. Overall, the latecomer city Dezhou displays a much less harsh selection environment for SWH diffusion in terms of user practices. On the other hand, the comparatively strong and homophilous social ties in latecomer cities not only facilitate the information flow of the innovation, but also exert a social conformity that pushes acquaintances to follow the adoption. Furthermore, the social proximity between users and producers in latecomer cities also strengthens the trust relations between them. Admittedly, the transition to SWH in Dezhou is a combined result of interaction between both the production and consumption sides, and user practices only map part of the whole story. This research contributes to an in-depth understanding about the role of users in sustainability transitions, which, we believe, lies in not only their individual preferences that offer an indication directing transition, but also their place-based social ties that help to form a close niche network containing both the demand and supply side to facilitate transitions.

In addition to justifying the integration of place and space into transitions studies, this research demonstrates the underestimated role of latecomer cities in sustainability transitions, thus, contributing to a deeper understanding of transitions in ordinary cities, rather than mere focusing on the most advanced modern cities. It also suggests practical implications for transitions

practices to pay more attention to latecomer cities, which may have a favoured position in sustainability transitions as they have not yet been locked-in by existing unsustainable technology regimes. To some extent, latecomer cities could provide a protected space for those green innovations that are not ready to compete in harsher selection environments. These niche innovations may eventually develop enough strength to reconfigure urban spatial arrangements through urban political processes, resulting in 'transition *of* cities' rather than 'transition *in* cities' [79]. It is therefore advisable to purposively harness strong social ties at the community level in latecomer cities to promote environmental innovations. Considering their relative backwardness in technological and financial capacities, latecomer regions may be more advised to develop less R&D- and capital-intensive green industries in the first place, so that they can get the utmost out of their latecomer advantages. Many successful innovations emerge from low-cost/low-tech alternatives [24]. Disruptive low-carbon innovations are also expected to improve their technology performance to cater to the more demanding markets, thus possessing the potential to grow from 'periphery-to-core'.

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