Cross-scale party alignment and public-private synergy: Polycentric governance of energy transitions with solar energy deployment in Taiwan, 2015-2020

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With the urgency of climate change, how local actions facilitate sustainability transition become an important research agenda in recent decades. The problem is about what may be conductive to the coordination of their efforts in stabilizing the climate. This is especially the case for local governments in East Asia which are conventionally less politically and fiscally autonomous than their western counterparts. Drawing on the theories of public good provision, this article examines the conditions in Taiwan which affect local energy transitions in terms of the varying levels of deployment of distributed solar energy (DSE) to de-carbonize the electricity sector from 2015 to 2020 with Qualitative Comparative Analysis (QCA). Five specific conditions are selected for the analysis: 1) urbanization level, 2) additional governmental subsidy, 3) economic affluency of a locality, 4) public-private synergy in local policy initiatives, and 5) cross-scale party alignment between the national and the local. Based on the findings, two pathways are identified. I argue that weak localities could also bring about higher level of solar energy deployment when it is embedded in the set of informal institutions of long national-local party alignment with high public-private synergy, together with either high additional governmental subsidy or the combination of low urbanization and low economic affluency of a locality. It implies that, while financial incentive is a crucial driver in a policy instrument for DSE in the two pathways, it is also important to focus on the informal multiple-level institutions for local energy transitions within weak localities in the East Asian context.

Keywords: Cross-scale, synergy, local government, energy transitions, QCA, Taiwan

Introduction

In recent decades, studies pay more attention to how the sub-national governments could also play a role in mitigating climate change, regardless of the stalemate at the international level. A body of exploratory literature works toward the theories of sub-national provision for global public good emerged for climate change mitigation. In the 1990s, there were pioneers of local governments which formulated transnational city-level network for climate protection (Bulkeley, 2014; Kern & Bulkeley, 2009; Lee, 2013). Globalization bring to the sub-national governments a new set of incentives to be concerned about the climate, which is manifest in local policy agenda such as carbon control (While, Jonas, & Gibbs, 2010) and resources security (Hodson & Marvin, 2010). For local governments to introduce more climate-friendly policies, studies suggest that the localities are likely to have liberal-leaning and higher educated constituencies (Hughes, Miller Runfola, & Cormier, 2018; Krause, 2011), larger population size and better socio-economic status of a locality (Lubell, Feiock, & Handy, 2009), slightly pro-environment party membership of the mayor (Yi & Feiock, 2014, p. 409), and a neighbouring locality which participate in similar programs (Krause, 2011; Pablo-Romero, Sánchez-Braza, & Manuel González-Limón, 2015).

The existing theories of sub-national provision for climate change mitigation predominantly focuses on the experiences in North America and Europe where the local governments are usually more politically and fiscally autonomous. For local governments in other contexts with less global economic interest, fewer engaged citizens about climate issues, and less fiscal resource in their command, they would have fewer selective incentives to pursue climate-friendly policy initiatives themselves, or even when the national climate policy is in place, they would not regard it as a high priority for implementation. In fact, changing the infrastructural system participated by many actors who are accustomed to "business as usual" is fundamentally political (Aklin & Urpelainen, 2013; Lockwood, 2017). Many local governments are thus entrenched in the existing infrastructural systems where they face financial, technical, institutional, and political barriers to climate policy formulation and implementation (Hughes, Yordi, & Besco, 2020, pp. 275-276).

Moreover, stabilizing the climate incurs huge coordination cost with the sheer size of actors involved, which poses a challenge to those sub-national governments lacking the incentives to act in the first place (Hale, 2020). Scant literature discusses how voluntary provision of global public good by localities can be motivated and coordinated in a different institutional context

such as the multi-level institution (Youm & Feiock, 2019, p. 780; Zhang, Li, & Yang, 2022, p. 10).

Also, the existing literature often conflates the scale of the "urban" and the "local" (Post, 2018, p. 118) when discussing local conditions which affect public good provision. They are conceptually different and have different implications for public good involving the urban infrastructural system. The "urban" emphasizes the physical aspect of local condition. It points to the distinctive policy domain it addresses and the specific kind of political economy it implies (Hochstetler, 2020). The "local", on the other hand, deals with the issue of accountability and responsiveness in the institutions to the daily lives of people on the ground (Agrawal & Ostrom, 2001). The "urban" concerns the problem structure of sustainability transition in spatial as well as sociological dimensions (Foster & Iaione, 2016), while the "local" in institutional and political dimensions. It is only when we conceptually distinguish them from each other that we can have a better understanding of how a variety of conditions affect voluntary provision of climate change mitigation through specific policies.

To refine the theories of sub-national provision for global public good, this article looks at energy transitions of Taiwan in East Asia involving different levels of government as well as non-state actors' participation from the perspective of institutional political economy. It adopts the Institutional Analysis and Development (IAD) Framework to examine the effects of multi-level institutions on the performance of energy transitions. It also does so by incorporating the theories of co-production and polycentricity. As the coal-intensive electricity sector is regarded as the culprit of carbon emission worldwide, increasing attention is given to how energy transitions toward decarbonization can be fastened with greater production of renewable energies. At the local level, participation in energy transitions is not necessarily restricted to state actors or big corporations. While many sub-national governments in cities were already directing resources toward energy transitions (Castán Broto & Bulkeley, 2013), there was also occasional civic activism to participate in small-scale renewable energies in the Global North (Seyfang & Haxeltine, 2012; Walker, Hunter, Devine-Wright, Evans, & Fay, 2007).

Despite the trend of neoliberalism in the reform on the electricity sector, the change required for energy transitions could not do away the role of state with its resources for foundational investment (Mazzucato, 2015), especially for the early stages of renewable energy deployment (Breetz, Mildenberger, & Stokes, 2018, p. 498). Also, the state is warranted for its role of coordination of multiple actors with public authority, as the process of energy transitions

involves the provision of global public good (e.g., climate change mitigation), national public good (e.g., energy security), national common good (e.g., infrastructure of electricity network) as well as individual private good (e.g., electricity unit from renewable sources). The simultaneous provision of these goods corresponds to public economies which involve both state and non-state actors (Ostroms & Ostroms, 1977).

Co-production and polycentricity

First developed by Vincent Ostrom and others, the theories of co-production argue that the involvement of government at different levels does not necessarily lead to inefficient provision of public good in a metropolitan area as one may envision with fragmentation, but they might be able to work collaboratively with the appropriate set of institutions to delimit their respective functions (V. Ostrom, Tiebout, & Warren, 1961). The theories suggest a distinction between "provision" and "production" of public good, and their synergy for higher level of efficiency with economies of scale. The former refers to "the process through which public good/service is made available to consumers", while the latter refers to "the material processes by which public good/service comes into existence" (McGinnis, 1999, p. 3). Besides, efficient provision of public good depends on a proper set of institutions to solicit the needed information with the right incentives to address the diversity of interests of actors across different scales (Aligică & Tarko, 2013, p. 727). The insight of co-production for efficient provision of public good is to engage the consumers of the public good who also have an incentive to produce it (E. Ostrom, 1996). A polycentricity in the set of institutions results when these autonomous and yet interdependent entities could cooperate efficiently toward the same objective with externalities of their respective actions largely coordinated (E. Ostrom, 2009). To further conceptualize polycentricity, Heikkila, Schlager, and Davis (2011, p. 122) argue that cross-scale institutional linkage is crucial for a polycentric institution to coordinate actors of multiple levels. In addition, Blomquist and Schröder (2019, p. 61) point out that the system needs to be able to cope with the resulting complexities, which involves risk, uncertainty, and exogenous shocks, and errors in learning and system collapse. In the context of local energy transitions, when local governments are not resourceful or politically autonomous, seeking collaboration with non-state actors is one of the ways to solve the problem. Drawing from these insights, this article ventures into an exploration of how multiple-level institutions could help weak localities to

pursue local energy transitions with solar energy deployment, and what local conditions may induce the involvement of multiple state and non-state actors for this purpose.

Taiwan's energy transitions: an overview

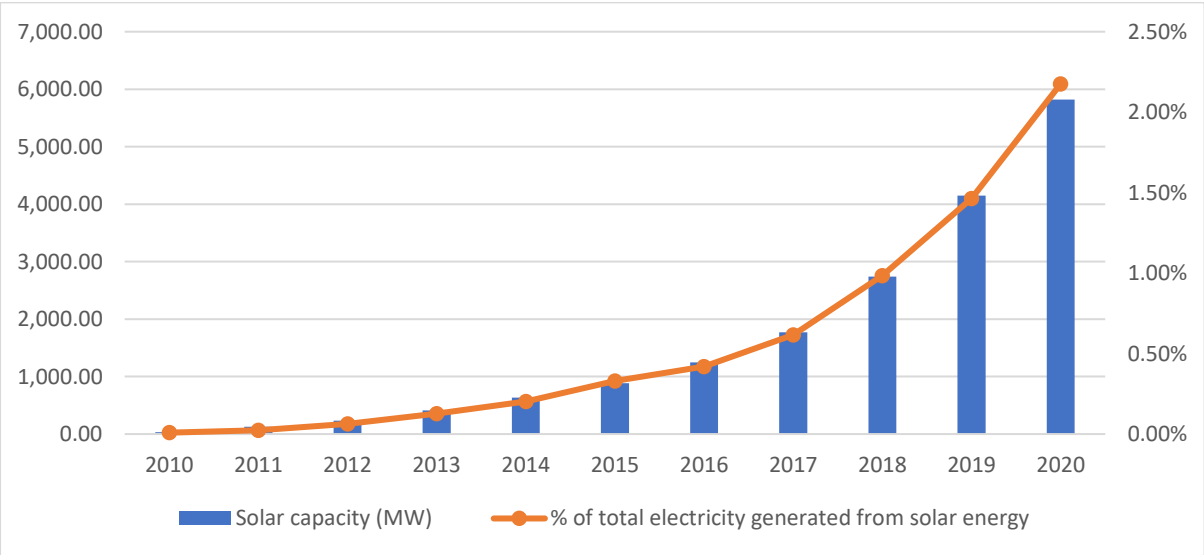
Energy transitions in Taiwan show potential to contribute to the theories of sub-national provision for global public good in two ways. First, East Asian political systems are largely characterized by an administrative legacy of national centralized policy formulation and national coordination of weaker local governments for implementation within a unitary political system (Kim & Thurbon, 2015, p. 230; Takao, 2020, p. 10). This allows us to go beyond the local level and pay attention to the multi-level institutional context for its institutional effect on facilitating the process of local energy transitions. Second, urbanization level of localities in East Asia varies to a great extent even within the same country. This permits a comparative study with regards to the urban dimension at the sub-national level, which is more significant when the public good in question involves infrastructure of electricity network which is well consumed by urban residents but produced far from the urban areas, constituting the physical interdependence of different localities.

Taiwan is characterized by a democratic two-party political system with a population of about 23.5 million. For governance, it has a *de-facto* three-layered unitary political structure with "Special Municipality" (*zhixiashi*) and "Counties and Cities" under the supervision of the Executive Yuan (i.e., the national-level government apparatus). All local governments rely on the national-level financial appropriation to varying extents, and special municipalities tend to have greater level of capacity and autonomies in most aspects. Local governments, especially those of smaller size, are characterized with elite clientelist networks in elections and services provision (Tang, 2003).

Similar to other countries, electricity generation from coal-fired plants is the culprit for carbon emission in Taiwan (Chou & Liou, 2020). At the national level, the discourse of energy transitions is to promote green industries as the new driver of economic development, not only for environmental sustainability but also for reducing reliance on the import of strategically crucial resources for energy security. Since 2009, the central government in Taiwan pursued

climate-friendly policy with the policy instrument of feed-in tariff[1] to promote renewable energies and decarbonize the electricity generation with the *Renewable Energy Development Act* (REDA).

Of the many types of renewable energy, solar energy capacity installation skyrocketed in the past decade. Overall, it increased from 35 MW in 2010 to 5,800 MW in 2020, with most of the increase took place in 2015-2020 (**Figure 1**). Since 2018, it is the largest among renewable energies in installed capacity. For electricity generated from solar energy, it increases from 0.01% in 2010 to 2.18% in 2020 of total electricity generated. The rapid rise could be partly attributed to the significant global production cost drop for photovoltaics in the 2010s (International Renewable Energy Agency IRENA, 2020), which makes it the most economically competitive type of renewable energy globally (Corrocher & Cappa, 2020, p. 8), and the dominance of the presidency and the parliament by the Democratic Progressive Party (DPP) which is traditionally more pro-environment than its political opposition the Nationalist Party (or Kuomintang, KMT) since 2016.



[1] Introduced in the 1990s and popularized by Germany (Leiren & Reimer, 2018), feed-in-tariff (FiT) is used as a policy instrument to encourage participation of multiple actors in renewable energy deployment by providing institutional guarantee for private investment associated with public benefits. It provides a guaranteed premium for a fixed period of years for non-state actors to produce renewable energy so that they could minimize the risk of investment (money, land, and expertise) over decades-long period and earn guaranteed return on their investment. The voluntary nature of the FiT as compared to other regulative policy instruments allows room for negotiation between stakeholders and the potential for wider distribution of benefits from energy transitions.

Figure 1: Taiwan's total installed solar energy capacity (MW) and percentage of total electricity generated from solar energy (%) in 2015-2020 (**Source:** TaiPower)

In line with the Paris Accord on Climate Change as the international agreement on carbon control (Li, 2016), Taiwan responded with the *Greenhouse Gas Reduction and Management Act* (GGRMA) in 2015, which assigns a greater responsibility for carbon control to the local governments as it demands the local governments to draft a register of carbon emission within their own jurisdictions and come up with a carbon reduction action plan for the central's approval. As a result, the central government rolled out more policy initiatives in addition to the FiT to boost up overall deployment in the second half of the 2010s. For example, it promulgated the "White Paper on Energy Transition" in 2017, which is intended to achieve the policy objective of reaching 20% of the electricity mix from renewable energy in 2025. It also established the "Office of Energy and Low Carbon" under the Executive Yuan in 2016 to coordinate ministries and local governments to implement the national carbon reduction targets. Virtually all localities have annual growth in DSE deployment in the period of 2015-2020. Nevertheless, localities in Taiwan exhibit varying levels of energy transitions in terms of annual deployment of solar energy (kW/km^2) (**Figure 2**). Some of these installations are the results of planned large-scale deployment (e.g., concentrated solar), but many others are of small scale as distributed solar energy (DSE) participated by a variety of non-state actors. Also, most increase in solar energy capacity is a result of non-state participation (**Figure 3**).

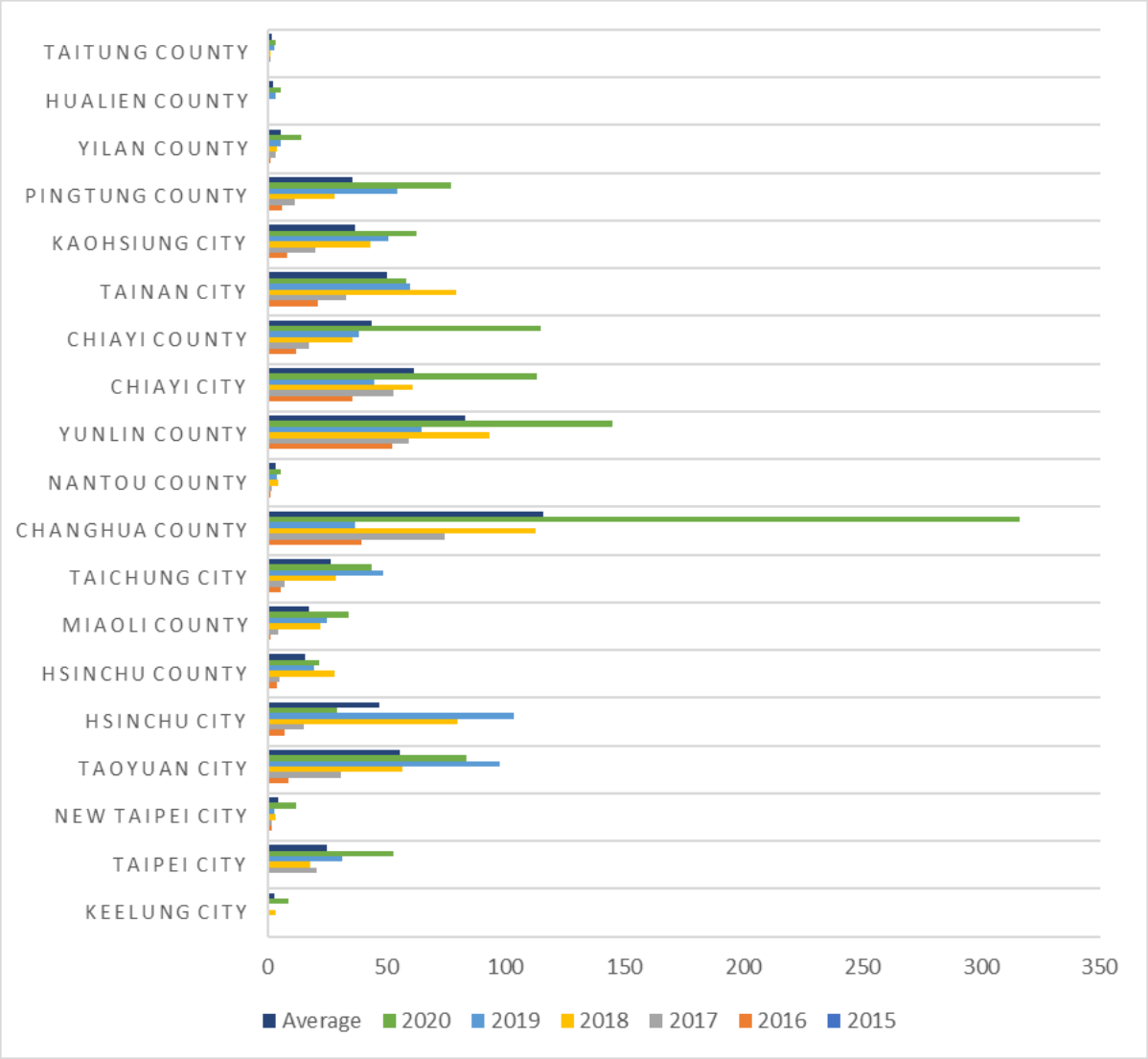


Figure 2: Annual expansion of distributed solar energy capacity (kW/km^2) by non-state actors by 19 Taiwanese localities in 2015-2020 (**Source:** Bureau of Energy, Ministry of Economic Affairs, Taiwan)

Besides the global production cost drop and the intensity of national policy initiatives, solar energy production is highly modular, and it allows flexible installation on the rooftop or on the ground in both urban and non-urban settings. This incurs relatively low entry cost and invites participation from actors with diverse backgrounds. Its benefit would be conditioned by the length of sunlight per year and the physical spaces suitable for DSE deployment. Because distributed solar can be relatively easily participated by multiple actors with lower entry cost, it constitutes the performance indicator of energy transitions in Taiwan for this article.

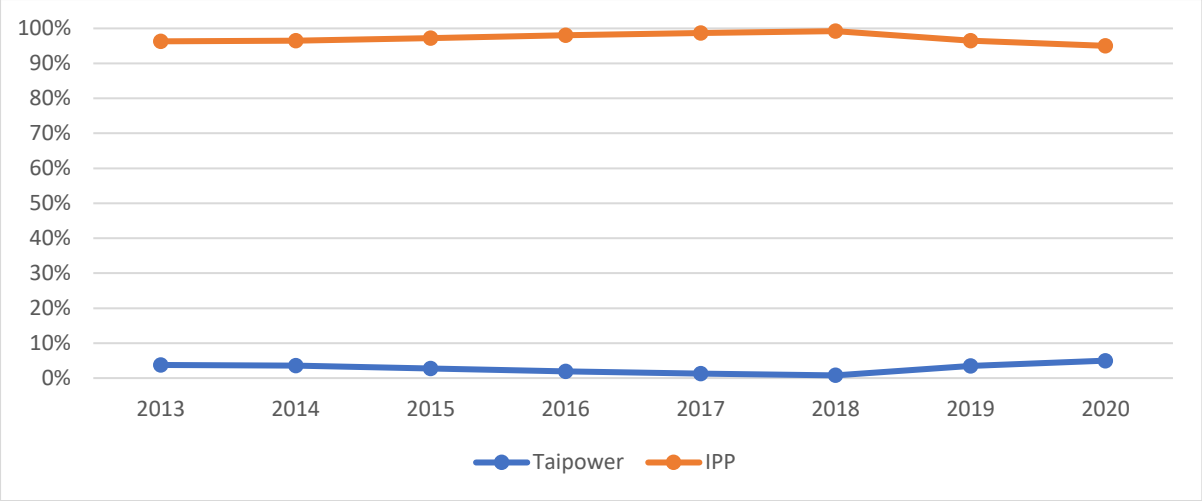


Figure 3: Ratio of Taipower's solar capacity relative to Independent Power Producer (IPP)'s solar capacity (**Source:** TaiPower)

Methodologies and data

To better account for the variations of annual DSE deployment in localities, this study employs a case-based comparative approach to the study of local conditions. Fuzzy-set Qualitative Comparative Analysis (fs-QCA) (Ragin, 2008) is adopted with the computational aid of fsQCA Software. QCA is designed to integrate the benefits of qualitative and quantitative approaches with the use of Truth Table to tackle complexity of the social world and the challenge of limited diversity of available data with counterfactual analysis. It is also conductive to the investigation into the combinational effect of conditions on the outcome of interest. Given the small number of cases under study, five conditions are identified after literature review. QCA is at times criticized of being prone to falsely accepting a hypothesis (Braumoeller, 2015), and conducting QCA on its own with a substantive interpretability approach may not carry sufficient explanatory power. This problem will be partly remedied by in-depth qualitative research on the cases and the application of sensitivity tests to propose a plausible causal mechanism embedded in the QCA results (Thomann & Maggetti, 2020).

Data and scope condition

For the volume of DSE deployment by non-state actors in each locality, they are collected from publicly available records from the official data of TaiPower and the governments in Taiwan for the period of 2015-2020. The data is fine-grained to exclude the installation by the state-

owned TaiPower to reflect the non-state participation from individuals, households, communities, and commercial companies intended by the FiT, but the data does not allow a distinction between these groups. For the data related to local conditions, they are compiled from the publicly available records from the government in Taiwan, supplemented by search for political events of localities with Wisenews Database for the period of 2015-2020. For the data of national and local policy responses, they are collected from the official documents of Greenhouse Gas Management Action Plans of all localities by the Executive Yuan, supplemented by a keyword search for relevant policy announcements and local-level activities related to solar energy with Wisenews Database for the period of 2015-2020. Interpretation of the QCA result is also supplemented by the data collected from personal interviews with practitioners and non-profit organization members conducted in 2019.

As the cases selected for study affects the results we get (Geddes, 2003), it is noteworthy to explain the rationale behind the scope condition. Due to the diversities in localities in Taiwan, all local jurisdictions are included for the study except for outlying island counties with largely different local profiles.[2] In total, 19 localities are under investigation. The study period is set at 2015-2020 for several reasons. First, the national government explicitly delegated more responsibilities as well as devoting more resources to the local governments for DSE deployment in the period, which fits the research purpose. Second, the DSE deployment has expanded considerably overall compared to the past but exhibits locally identifiable variations in the period. Third, the period is considered as appropriate since there is no major revamping of local political institution to change jurisdictional boundaries, which was the case in Taiwan in 2014. Fourth, the period deliberately sets to overlap with the presidential tenure (2016-2019) so as hold the national policy direction for DSE deployment constant in the two-party system. In the next section, the five conditions under study are further elucidated.

Conditions for DSE deployment

The selection of local conditions under study is made with reference to the IAD framework with biophysical constraints (Condition 1), socioeconomic attributes of localities (Condition 2 & 3), existing rules-in-use (Condition 4 & 5), the multiple profiles of individual actors (E.

[2] Namely, they are Lienchiang County, Penghu County, and Kinmen County, for they are categorially different from other localities in terms of population size, geopolitical position, and level of economic development.

Ostrom, 2011) as well as the specific context of Taiwan.[3] The overarching logic of condition selection is attributed to their potential effect on *generating new interests* of individual actors (including local politicians, local property owners, and owners of energy service companies (ESCO)) in pursuing solar energy deployment in the context of energy transitions.

Condition 1: Urbanization level (URBAN)

Geographical factors undoubtedly affect infrastructural good provision in general and DSE deployment in particular. For one thing, the physical landscape characterized by urbanization level determines the feasibility and scale of DSE, conditioned by meteorological factors which determine sunlight availability and strength.[4] These affect the level of incentives for non-state actors to provide private information and resources for DSE deployment. Moreover, in line with the call for bringing the urban back in, the urban setting with a large population size and fragmented propertied resources make DSE deployment more challenging as well (Takao, 2020, p. 2).

Condition 2: Additional governmental subsidy (AGS)

Fiscal capacity can be one important factor for the local governments to make pro-environment policy responses (Krause, 2012; Lubell et al., 2009; Pablo-Romero et al., 2015). Budget constraint could bar them from employing specific policy instruments such as funding non-state actors for retrofit measures with subsidies (Hughes et al., 2020). For non-state actors, governmental subsidy is also found important to attract their investment in solar energy (Sawin, 2004, pp. 38-41). While local governments in Asia tend to have weak fiscal capacity, they could appeal to higher-level governments for inter-governmental grant on top of the national FiT. In Taiwan, virtually all local governments depend on the national government for financial appropriation to some extent. For DSE deployment in the studied period, additional national

[3] In October 2019, the Control Yuan, which is the institutional body responsible for the monitoring of the exercise of administrative power of the Executive Yuan in Taiwan, criticized the administrative delays in carrying out plans of carbon reduction since 2015 (The Control Yuan, 2019). One possible reason is that the politicians and government officials of local governments entrusted with the task did not really have the knows-how (Lai, 2019). For this reason, carbon emission is not considered a significant condition for DSE deployment in the studied period.

[4] The factor of sunlight strength which remains stable over decades. While being important in the actual payoff of DSE investment, it is treated as a latent condition necessary for the outcome but not included in the model.

grants are allocated to some local governments by the national government for this purpose. Some dedicated grants are given to support specific local projects. For some fiscally stronger localities, the local governments also give out additional financial reward for non-state solar energy installation on top of the national feed-in tariff. Additional government subsidy falls under these categories, regardless of the level of government the subsidies are provided.

Condition 3: Economic affluency of local participants (INCOME)

As renewable energy requires suitable sites for installation, the local support from property owners who make lands available or from residents who do not oppose its sitting becomes important. While non-state participation in DSE under the FiT can certainly be motivated by heterogenous motives such as environmental concerns and social norms, financial incentive remains a reliable determinant (Bauwens, 2016; Fischer, Gutsche, & Wetzel, 2021). Local ownership of distributed solar energy is found instrumental to the acceptance of renewables installation in pioneering countries such as Germany (Hager & Hamagami, 2020, p. 393). The income level of a locality is thus relevant because it determines the degree of which DSE is regarded as a sufficient financial incentive for residents to adopt DSE.

Condition 4: Local policy initiative to promote DSE with public-private synergy (SYNERGY)

Public-private synergy refers to the joint achievement of the same outcome between the state and non-state actors (complementarity), with a layer of informal social network between these actors (embeddedness) (Evans, 1997, p. 8). To ascertain the degree of which local solar energy policy involves the element of public-private synergy rather than state provision alone, a qualitative data analysis of official documents as well as media reports from a digital news archive is conducted for the studied period. Policy initiatives with the engagement of non-state actors for DSE deployment are put into two categories: 1) "production-oriented", and 2) "provision-oriented". In terms of the number of involved non-state actors in the types of policy initiatives, the former is regarded as "low" degree of public-private synergy and the latter as "high". Detailed results are shown in **Figure 4** on which the calibration of data for QCA is based.

Degree of public-private synergy	Low		High	
Type	Production-oriented policy initiatives		Provision-oriented policy initiatives	
Sub-type	Administrative	Administrative	Institutional/legal	Organizational
County/City	Small-scale deployment through public tendering	Large-scale solar energy deployment through public-private partnership (>1 MW)	Relaxation of legal restriction/Legal allowance for DSE	Partnership with solar energy trade unions/commercial banks/companies
Keelung City	Yes	No	No	No
Taipei City	Yes	No	No	No
New Taipei City	Yes	No	No	Yes
Taoyuan City	Yes	Yes	Yes	Yes
Hsinchu City	Yes	Yes	Yes	Yes
Hsinchu County	Yes	No	No	No
Miaoli County	Yes	No	No	No
Taichung City	Yes	No	Yes	No
Changhua County	Yes	Yes	Yes	Yes
Nantou County	Yes	No	No	No
Yunlin County	Yes	Yes	Yes	Yes
Chiayi City	Yes	No	Yes	No
Chiayi County	Yes	Yes	No	No
Tainan City	Yes	Yes	Yes	Yes
Kaohsiung City	Yes	Yes	Yes	Yes
Pingtung County	Yes	Yes	Yes	Yes
Yilan County	Yes	No	No	No
Hualien County	Yes	No	No	No
Taitung County	Yes	No	No	No

Figure 4: Degree of public-private synergy in local solar energy policies by 19 Taiwanese localities in 2015-2020

Condition 5: Local party alignment with pro-environment national-level leaders (ALIGN)

This condition corresponds to the institutional linkage across the national and the local to coordinate actions by actors at multiple scales. For a unitary system, the formal institution generally restricts political and fiscal autonomy of local governments than the federal system to deviate from the policy parameters set by the national government, but covert conflicts could also arise because of the principle-agent problem within a hierarchical administrative structure. Meanwhile, local innovations may not be able to scale up given the rigidity of the existing policy of the national government.

In a two-party political system, national-local relations can be more cooperative when the leaders come from the same political parties or more conflictual when not. The informal institution within the same political party serves to coordinate policy across scales. For less resourceful local governments to orchestrate with the national initiatives, cross-scale party alignment provides an additional layer of institution for sharing resources and shaping local political priorities. The incentives for subordinate party members to follow the directives of party's central leaders come from the centrality of the party's decision-making process to determine the candidature of party members for elections at local as well as presidential/parliamentary elections, and for promotion to a higher position within the governmental apparatus, which corresponds to the situations in Taiwan.[5] In the studied period, the DPP not only holds both the presidency and the parliamentary majority at the national level, but development of renewable energy is also high on the political agenda as the DPP chairperson cum the president emphasized in her presidential inauguration speeches in May 2020 to turn Taiwan into the Asia-Pacific Green Energy Centre (Tsai, 2020). These lend support for the utility of the intra-party mechanism to mobilize the DPP-affiliated leaders of local governments to promote DSE within the localities.

Analyses

For fs-QCA, calibration is an important step. The aim of the process is to convert qualitative information into numeric terms and to show the relationship between the conditions and the outcome in a set-theoretic logic. The calibration criteria for the outcome and the five conditions are noted in **Figure 5**. Direct method of calibration which assigns a benchmark for membership based on the qualitative understanding of the cases under study is used.

[5] Certainly, it is clearly not the full picture as it needs also to consider the factional politics within the political party. The meritocratic assessment by the party leaders is not, however, completely irrelevant. Not only can it become a resource for discursive politics, but it could also be a show of loyalty to certain factional leaders within the political party.

Outcome and conditions	Operationalization	Calibration (on a scale of 0.1)	Symbols
Outcome			
High-level annual expansion of DSE	Average annual increase in the capacity of distributed solar energy installed in a locality (kW/km^2) from 2015 to 2020	It is in the membership (> 0.5) when the outcome is above the median value of the average annual variations of all localities under study (i.e., 33kW/km^2)	**DSE (Presence)** **dse (Absence)**
Conditions[6]			
High level of urbanization (-)	Average population density of a locality and economic activities of population in 2015	It is in the membership (> 0.5) when it meets two criteria: - The average population density of the locality is higher than the median of all localities under study (i.e., 900 person/km^2)[7] - No more than 10% of population is employed in the agricultural sector in the locality	**URBAN (Presence)** **urban (Absence)**
High level of additional governmental subsidy[8] (+)	Governmental subsidy available to all non-state actors for DSE installation within respective locality on top of the FiT (regardless of the level of government from which the subsidy comes) prior to 2018	It is in the membership (> 0.5) when: - It is in the northern region eligible for 15% of additional subsidy by the national government (0.6) - It has a subsidy scheme in place for more than 2 years by 2018 (0.6) - It is in the designated northern region and has a subsidy scheme in place for more than 2 years by 2018 (0.7-0.9)	**AGS (Presence)** **ags (Absence)**

[6] Directional expectation of each condition for the outcome is noted in parathesis where "+" denotes positive and "-" denotes negative impacts.

[7] This median value is adopted with reference to how the UN considers urban area in Asian countries such as (India: 400 person/km^2) and China (1,500 person/km^2). (UN Demographic Yearbook, 2015).

[8] There is a potential problem with endogeneity which exhibits simultaneity between the condition and the outcome of interest as grants and subsidies could be increased to boost DSE deployment when installation level is low or vice versa. In the studied period, no additional governmental subsidy has been reduced but increased in any locality in Taiwan. Also, only subsidies provided prior to 2018 is included in the calibration to allow the effect of previous policy to take hold and to minimize the potential reverse effect of the installation level on this condition.

High level of economic affluency of a locality (-)	Annual income level of worker of a locality in 2015	It is in the membership (> 0.5) when it is above the median value of the variations of all localities under study (i.e., $648,000 NTD)	**INCOME (Presence) income (Absence)**
High degree of public-private synergy in local solar energy policies (+)	Presence of either production-oriented policy initiatives within 2015-2020 and/or provision-oriented policy initiatives prior to 2018	It is in the membership (> 0.5) when it has provision-oriented policy initiatives prior to 2018 - When it has institutional/legal or organizational type (0.6) and both (0.8)	**SYNERGY (Presence) synergy (Absence)**
High level of local party alignment with pro-environment national-level leaders (+)	Length of years in which mayorship and presidency are held by the persons of the same political party from 2016 to 2020	It is in the membership (> 0.5) when: - Central-local party alignment lasts for 3 years or more within 2016-2020 (0.6) - Party alignment is longer than 3 years (0.7 – 0.9) - On top of the length of party alignment, mayors and the president are perceived as within the same intra-party faction (addition of 0.1)	**ALIGN (Presence) align (Absence)**

Figure 5: Operationalization of five conditions for the outcome of high DSE deployment in locality

Findings

To read the result of the fs-QCA, we need to consider "consistency" and "coverage" to understand the necessity and sufficiency of the combined sets of conditions. Consistency refers to the degree of necessity of the set of conditions for the outcome of interest (internal validity), while coverage refers to the degree of sufficiency among other alternative paths to the outcome of interest (external validity). For this study, consistency threshold is set at 0.85 or above as suggested for small-N group (Ragin, 2008), and coverage threshold is set at 0.7 or above.[9] Standard Analysis is subsequently employed to find out the intermediate solutions for high annual expansion of DSE deployment. To test the robustness of the results, several sensitivity tests are conducted according to the suggestions by Skaaning (2011), such as modifying the consistency threshold from 0.85 to 0.90, the frequency threshold from 1 to 2 in consideration of the small number of cases involved, and the calibration threshold of the outcome within ± 20% band of the original benchmark. Also, a separate analysis for the negation of the result (i.e., low DSE annual increase) are also conducted to check potential contradictory assumptions about the conditions (Schneider & Wagemann, 2013). More details about the QCA solutions are shown in **Figure 7.** The central model (overall consistency at 0.89 and coverage at 0.72) is expressed below where conditions with capital letter indicates "presence" and if not "absence"; "*" indicates the logic of "AND" and "+" indicates "OR":

ALIGN*SYNERGY*AGS + ALGIN*SYNERGY*urban*income → DSE

The QCA solution can then be re-formulated as follows:

ALIGN*SYNERGY* (AGS + urban*income) → DSE

Two pathways to more successful local energy transitions are identified from the QCA. The findings suggest that the combination of long cross-scale party alignment and local policy with high public-private synergy are necessary conditions for higher level of DSE deployment in a

[9] There is no consensus as of now about the appropriate score for coverage in QCA (Haesebrouck & Thomann, 2021). Reasonably, low coverage score denotes that the solution type has low degree of external validity, but it does not suggest that it is empirically unimportant or the prime implicants suggested in the model is not scientifically valid, provided that the solution type has a reasonable consistency score (Schneider & Wagemann, 2013, p. 148).

locality. When they are combined with either larger governmental subsidy, or the combination of less urbanized areas and a less economically affluent population, it is likely to achieve higher level of DSE deployment in a locality. As shown in **Figure 6**, the results of sensitivity tests also suggest this necessity consistently.

Pathway code	Result	Solution type	Frequency threshold	Consistency threshold	Overall Consistency	Overall coverage	Solutions (FULL)	Raw coverage	Unique coverage	Consistency	Cases involved
	Central model										
[1]		Intermediate	1	0.85	0.89^	0.72	ALIGN*SYNERGY*AGS	0.56	0.22	0.87	TYC, TNC, KHC, HCC, TCC, CYC, PTT
[2]							ALGIN*SYNERGY*urban*income	0.49	0.16	1.00	YLT, YNC, PTT
	Sensitivity tests										
[3]	**Higher consistency threshold (0.9)**	Intermediate	1	0.90	0.89^	0.72	ALIGN*SYNERGY*AGS	0.56	0.22	0.87	TYC, TNC, KHC, HCC, TCC, CYC, PTT
[4]							ALIGN*SYNERGY*urban*income	0.49	0.16	1.00	CCT, YLT, TNC, PTT
[5]	**Higher Frequency threshold (2)**	Intermediate	2	0.85	0.89^	0.72	ALIGN*SYNERGY*AGS	0.56	0.22	0.87	TYC, TNC, KHC, HCC, TCC, CYC, PTT
[6]							ALIGN*SYNERGY*urban*income	0.49	0.16	1.00	CCT, YLT, TNC, PTT
[7]	**Lower threshold for "high" DSE (>=26.kW/km2)**	Intermediate	1	0.85	0.95^	0.68	ALIGN*SYNERGY*AGS	0.54	0.24	0.94	TYC, TNC, KHC, HCC, TCC, CYC, PTT
[8]							ALGIN*SYNERGY*urban*income	0.44	0.14	1.00	CHT, YLC, TNC, PTT
[9]	**Higher threshold for "high" DSE (>=39.kW/km2)**	Intermediate	1	0.85	0.80	0.72	ALIGN*SYNERGY*AGS	0.54	0.21	0.75	TYC, TNC, KHC, HCC, TCC, CYC, PTT
[10]							ALGIN*SYNERGY*urban*income	0.51	0.18	0.93	CHT, YLT, CYT
	Negation of outcome										
[11]		Intermediate	1	0.90	0.90^	0.80	align*synergy	0.60	0.15	0.89	TPC, HCT, MLT, NTT, HLT, TTT
[12]							AGS*synergy	0.59	0.16	0.98	TPC, KLC, HCT, MLT, YLT, HLT, TTT
[13]							align*URBAN*INCOME	0.31	0.37	0.85	TPC, NTC

Figure 6: fs-QCA solutions for central model, negation of outcome, and sensitivity tests (Consistency scores with "^" are considered valid)

Discussions

With regards to the necessary conditions, longer national-local party alignment across scales serves as an informal institution to facilitate the implementation of national policy with regards to energy transitions as it helps mobilizes mayors to set DSE deployment at a higher priority on their local agenda in line with the national one, and to coordinate relevant government agencies of the local government to achieve a better policy outcome (Takao, 2020). Longer period of cross-scale party alignment functions to be a more trustworthy conduit to channel local feedback and innovative strategies to the national level and allowing mayors to fine-tune local policy initiatives dynamically when it involves the uncertainties surrounding non-state participation at the local level. In addition, the cross-scale party alignment works in a unitary system by inducing competition between leaders of local governments for higher political positions within the same political party and the government apparatus. In this sense, cross-scale party alignment incentivizes local politicians to be sensitive to the problems of solar energy deployment at the local level, making timely adjustments when needed. The incentive for constant review of policy implementation is important as energy transitions involve high level of uncertainty in many dimensions (Isoaho & Markard, 2020, p. 344). The practices of innovative policy measures suitable to the local conditions are thus better regarded as a trial-and-error process than a one-off event. In the polycentric context, cross-scale party alignment works because it helps induce competition among mayors to mobilize local resources, but at the same time prevent it from going out of control. The findings also qualify that pro-environment mayoral partisanship is important as in the literature, but it is more important if the mayoral partisanship matches that of the national one with a national-local party alignment.

One concern about the condition of national-local party alignment is the possibility that the result could be confounded by other factors when the party in question is also a pro-environment one. It is possible that the party alignment is due to confounding conditions such as "liberal-leaning" or "highly educated" constituency favouring pro-environment candidates in local and presidential elections (Krause, 2011). In the case of Taiwan, environmental concerns have gained traction in local elections since 2011 (Grano, 2015), and the majority of voters is supportive of decarbonization of the electricity sector as indicated in the results of the 2018 nationwide referendum (Central Election Commission, 2018). Nevertheless, despite such public attention and support for decarbonization, there is far from clear how to achieve the goal. For DSE deployment with the participation of individual actors, a nation-wide public opinion survey in 2019 shows that over 40% of them is uninterested in participating in DSE and only

4% of them has installed solar panels (Great Society Survey Center, 2019). It matches the observations by practitioners that most of the DSE installation by 2019 were dominated by small-and-medium PV-ESCOs (Personal Interview, 2019). These suggest a qualification that the mayoral or presidential candidates who promote DSE deployment in their electoral manifestos do not have a considerable advantage for re-election, but they do not stand a higher chance to lose either. Hence, the condition of pro-environment electorate is irrelevant as far as local DSE deployment is concerned. In a situation where politicians consider their positions are relatively secured, political party's ideological inclination can prevail in policymaking for the long term (Jacobs, 2011). It renders the informal coordination mechanism within the ruling party more pronounced on the local political agenda.

Moreover, the long cross-scale party alignment which incentivizes mayors logically complements the high degree of public-private synergy in local policy initiatives. Local governments do not have sufficient resources to survey the resources available for solar energy deployment, but they could make convenient for non-state actors who have such information or are incentivized to fetch such information. Hence, local policy with high degree of public-private synergy is conductive to higher DSE deployment. By nurturing a wider group to engage in DSE, higher degree of public-private synergy in local policy initiatives also circumvents the traditional vested interests in the coal-based electricity sector and makes a breakthrough in energy transitions as designed by the national government.[10] Corresponding to the data shown in **Figure 3**, over 95% of the solar energy capacity is added by non-state actors rather than TaiPower in the studied period. Public-private synergy helps explain the rapid growth in DSE deployment compared the period prior to 2015.

On top of the necessary conditions, the finding about high level of additional governmental subsidy as one favorable condition for higher annual increase of DSE deployment is not surprising as it represents better more financial incentive for non-state actors, which is in line with previous research (Bauwens, 2016; Lubell et al., 2009). In the multi-level institutional setting, additional financial incentive does not necessarily come from the localities but could

[10] Parallel to the development of DSE is the liberalization of the electricity sector which was previously monopolized by the state-owned utility Taiwan Power Company (TaiPower). Despite TaiPower's attempt to retain dominance in the electricity sector, its breakdown of TaiPower's monopoly is materialized with the amendment to the *Electricity Act* in 2017, which prioritizes the use of renewable energy and allows for the first time the sale of renewable energy by non-TaiPower entity with a view to creating a market for renewable energy exchange in the future

be provided by the national government as well, which is particularly crucial for localities of less fiscal capacity.

Less urbanized area and low economic affluency of a locality are also found favorable conditions for DSE deployment because less urbanized areas provide more spaces for more economically efficient operation of solar panel installation, and residents with less socio-economic profile are more motivated by the economic incentive of DSE compared to the production and transaction costs involved in the participation. Similar findings about the benefits of lower economic affluency and land availability are also obtained by another method of analysis in the East Asian context (Fraser, 2020). The findings demonstrate the importance of distinguishing the urban characteristics of a locality when it comes to implementing policy change for urban infrastructure such as the electricity network. Also, it points to an interesting paradox that local energy transitions with voluntary-based policy instruments are less likely to take place in urbanized areas where carbon pollution is principally made, but in less urbanized areas. It implies that local energy transitions are hardly achieved by isolated localities, but their cooperation. It thus supports the claim that theories of sub-national provision for global public good in the context of local energy transitions need to go beyond individual localities as most literature previous focus, and re-direct attention to the multi-level institutions these localities are embedded in.

Conclusion

This paper discusses how the existing theories of sub-national provision for global public good for climate change mitigation can be refined with reference to the theories of co-production and polycentricity. It examines the process of energy transitions in the East Asian context with the localities in Taiwan and investigates the combined effect of five selected conditions on the performance of local energy transitions indicated by the annual increase in solar energy capacity deployment from 2015 to 2020. With fussy-set Qualitative Comparative Analysis and in-depth investigation of local contexts, the findings suggest two pathways for more successful local energy transitions. The combination of long national-local party alignment and high public-private synergy in local policy initiatives are necessary for high performance of local solar energy deployment. Together with these informal multi-level institutions, either high level of additional governmental subsidy or the combination of low economic affluency and less urbanized area of a locality can also facilitate local distributed solar energy deployment

under the national feed-in tariff. The rationale lies in that long cross-scale party alignment induces modest competition among mayors of the same political party, while high degree of public-private synergy encourages informal cooperative relationship between local government and a wider range of non-state actors.

Three previously neglected issues are highlighted with the findings and analysis in this paper. First, we need to pay attention to multi-level institutions in which weak localities are embedded to better examine the possibility of wider sub-national provision of global public good through local policy initiatives. Second, the urban characteristic of a locality deserves a conceptual distinction from the local condition when it comes to a change in the urban infrastructure for better clarity in analysis, which is crucial to better understand the feasibility of policy implementation and the need for the cooperation among localities. Third, sub-national provision of public good for climate change mitigation deals with institutional change by default as the conventional mode of modern development is unsustainable. Theories of co-production and polycentricity shed light on how new vested interests could be nurtured to break the path-dependency of existing mode of public good provision with uncoordinated externalities with the new provision of mixed types of goods.

One limitation of this paper is its reliance on the annual increase in solar energy capacity in a locality as the sole indicator of successful local energy transitions. This could run the risk of goal displacement from environmental protection considering that the process involves the provision of mixed types of good. In Taiwan, after some years of enthusiasm for DSE, there is increasing number of reported conflicts between the lucrative DSE deployment with the relatively unprofitable agricultural land use as well as biodiversity conservation. This problem of land grabbing is not unique to Taiwan but also phenomenal globally (Scheidel & Sorman, 2012). Although national feed-in tariff is designed as a policy initiative of "yes-in-my-backyard" nature, conflicts arising from local DSE deployment could change the policy initiative into the one of "not-in-my-backyard" nature with the fading of public support for energy transitions (Breetz et al., 2018). Success of local energy transitions requires a long-term time horizon, and it hangs upon the continued legitimization from the public (Hager & Hamagami, 2020). Future research may incorporate additional indicators such as social equity when assessing local energy transitions.

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