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Power Sector Asset Networks: Determinants of the Diffusion of Renewables

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Between 2007 and 2017 generating capacity of grid-scale (>1MW) solar photovoltaic, wind, and bio-energy ('renewables') increased from 484GW to 1,442GW – 6.5% and12% of total generating capacity respectively.[1] The International Energy Agency (IEA) projects that to achieve a sustainable development pathway that meets the development needs of the global South while constraining warming to less than 2ºC, the installed capacity of renewables must increase to 6,664GW and 51% of all generating capacity by 2040.[2] Understanding how power generating companies choose to adopt renewable generating options is crucial to devising both domestic and multilateral climate policy, and to inform corporate strategy which must manage the threats and opportunities that renewables pose to their business models.

Peer and network effects are widely recognised for their influence in the diffusion of technology in Schumpterian models of innovation.[3] Examples include the diffusion of computers,[4] domestic solar PV systems,[5] and cell phones.[6] A network innovation model composed of company and country nodes provides a convenient framework for examining a number of extant questions in transitioning power systems:

- How do node and edge attributes, such as renewable energy policies, market structures, or market compositions impact the uptake of renewable energy generating options?
- Is there a peer learning effect whereby well connected or more significant nodes are able to change the behaviour of other nodes even in absence of stimulating policy? Such peer effects might hold promise for diffusing renewables even to countries who have been slow to adopt climate-friendly energy policies.
- Finally, might there be an unobserved global learning rate for renewables? Learning rates are used in many technoeconomic models of renewable technology adoption and are thus contentious parameters.

Data

The data for this study are drawn from the quarterly releases of S&P Platt's World Electric Power Plant Database (WEPP), the dataset of-record for global generating assets and their corporate owners. The data have been obtained for the period 2007 through 2017 – a crucial period which saw the first commitment period of the Kyoto Protocol, the growth of the EU ETS, a wide range of renewables obligations schemes and subsidies, and the rapid growth of the power sector in large critical economies in the global South, notably China and India. The asset-level data provided by WEPP is feature-rich with attributes ranging from the generating capacity of the power station through to data on pollution controls. Additional attributes for country nodes include the coverage of any carbon pricing schemes,[7] and cross-sectional assessments of policy support for renewables.[8]

Methods

Asset-level data are aggregated by company and by country to form the nodes of a bipartite social network. Network edges are drawn from portion of company assets located in each country. The company projection of the network yields a bidirectional graph with edge weightings corresponding

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1 S&P Global Platts (2018) *World Electric Power Plant Database, December 2017*, typical.
2 IEA (2017) *World Energy Outlook 2017,* Paris, France.
3 E.g. Grübler, A. (1996) *Time for a Change: On the Patterns of Diffusion of Innovation,* IIASA, Laxenburg, Austria.
4 Goolsbee, A, & Klenow, P. J. (2002) 'Evidence on learning and network externalities in the diffusion of home computers', *Journal of Law and Economics,* 45(2): 317-343.
5 Bollinger, B. & Gillingham, K. (2012) 'Peer effects in the diffusion of solar photovoltaic panels', *Marketing Science,* 31(6): 900-912.
6 Tony Ke, T. & Yang, C. Z. (2017) *Peer Effect of iPhone Adoptions on Social Networks*, MIT Sloan Research Paper No. 5177-16.
7 World Bank Group (2017) *State and Trends of Carbon Pricing 2017*, Washington DC.
8 REN21 (2017) *Renewables 2017 Global Status Report*, Paris, France.

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to the country co-location of assets between nodes, on the assumption that social ties will be strongest where companies have assets which participate in the same power markets, hire the same consultants and contractors, etc.. A fixed-effect model is prepared adapting similar methods to Manski,[9] Tucker,[10] and Ke & Yang,[11] where the time-varying renewable portion of a company *i*'s generating mix, *GREEN,* is dependent on the company's attributes, α, it's co-located assets with other companies in the network, a time effect variable γ, and a uniform error component ε, see Equation 1.

Equation 1

$$GREEN_{i,t} = \beta_1 COLOCATED\_ASSETS_{i,t} + \sum_{j\ in\ ATTRIBUTES} \alpha_{i,j} + \gamma_t + \varepsilon_{i,t}$$

Two ideal outcomes for this work at the SusTec Academy would be i) the identification of additional datasets to enable causality testing via an instrumental variable model, and ii) identification of other network diffusion models to inform the robustness of the findings.

Early Findings

Analytical findings are still in development, however network visualisations have been prepared for the first and final time periods, shown in Figure 1. The change in size and complexity of the network, and extent of renewables penetration between the two time periods is apparent. The developed paper will also include more formal assessments of time-varying assortativity and centrality measures and the implications thereof on the transition of the global power sector to sustainable energy generation.

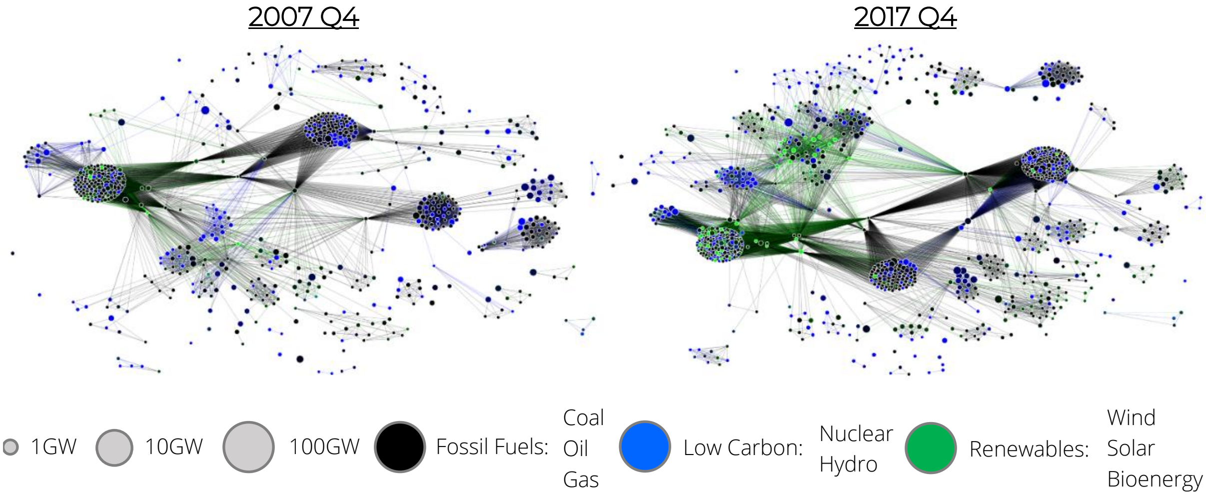

Figure 1: Company-projection of global generating assets network, 2007 and 2017

About the Authors

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[9] Manski, C. F. (1993) 'Identification of endogenous social effects: The reflection problem', *The Review of Economic Studies,* 60(3): 513-542.
[10] Tucker, C. (2008) 'Identifying formal and informal influence in technology adoption with network externalities', *Management Science,* 54(12): 2024-2038.
[11] Tony Ke, T. & Yang, C. Z. (2017) *Peer Effect of iPhone Adoptions on Social Networks*, MIT Sloan Research Paper No. 5177-16.