Green technology diffusion: a network perspective

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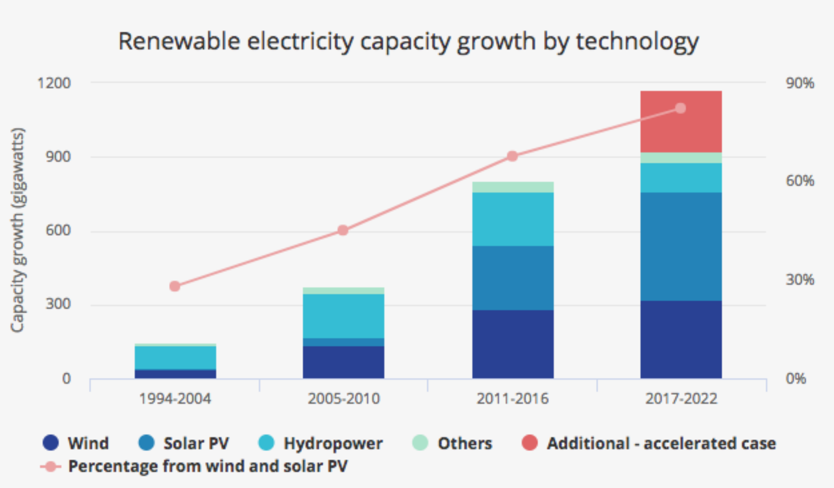
Technology diffusion and climate policy

Diffusion of low-emission technology key in climate policy:

"Parties, noting the importance of technology for the implementation of mitigation and adaptation actions under this Agreement and recognizing existing technology deployment and dissemination efforts, shall strengthen cooperative action on technology development and transfer."

(The Paris Agreement, Article 10.2)



Source: IEA Renewables 2017

Technology diffusion and climate policy

Previous work on the diffusion of renewables:

- adoption analyses
(Popp et al., 2011; Pfeiffer and Mulder, 2013; Polzin et al., 2015)

- patent data
(Dechezleprêtre & Glachant, 2014; Verdolini & Bosetti, 2017)

- data from the Clean Development Mechanism
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Here: Diffusion can involve network effects
(Hidalgo et al., 2007; Chaney, 2014)

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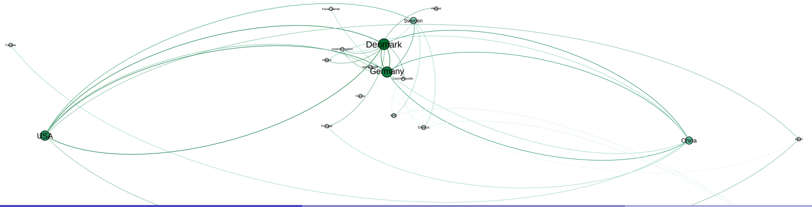
Halleck Vega, S. and Mandel, A., 2018.
Technology diffusion and climate policy: a network approach and its application to wind energy. Ecological Economics 145, 461-471.

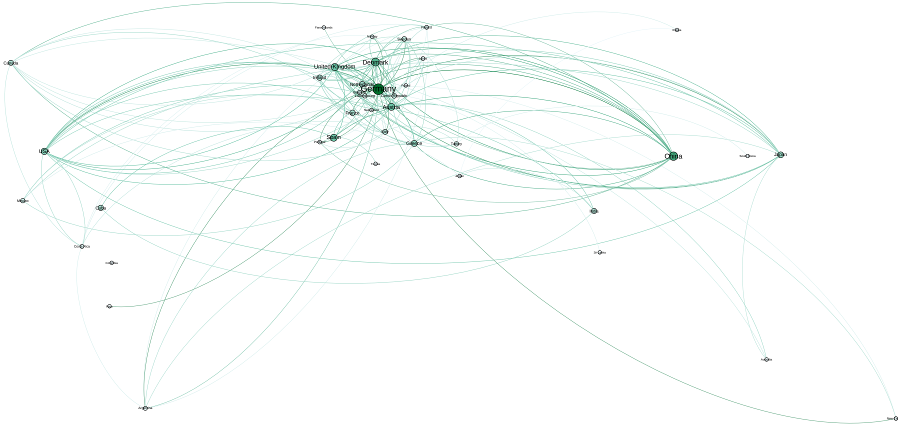
Halleck Vega, S., Mandel, A., and Millock, K., 2018.
Accelerating diffusion of climate-friendly technologies: a network approach. Ecological Economics 152, 235-245.

APPLICATION

- Use actual data on diffusion of an important renewable energy technology.
- The "WindPower" database (1983-2016):

  223 wind technology diffusion cascades.

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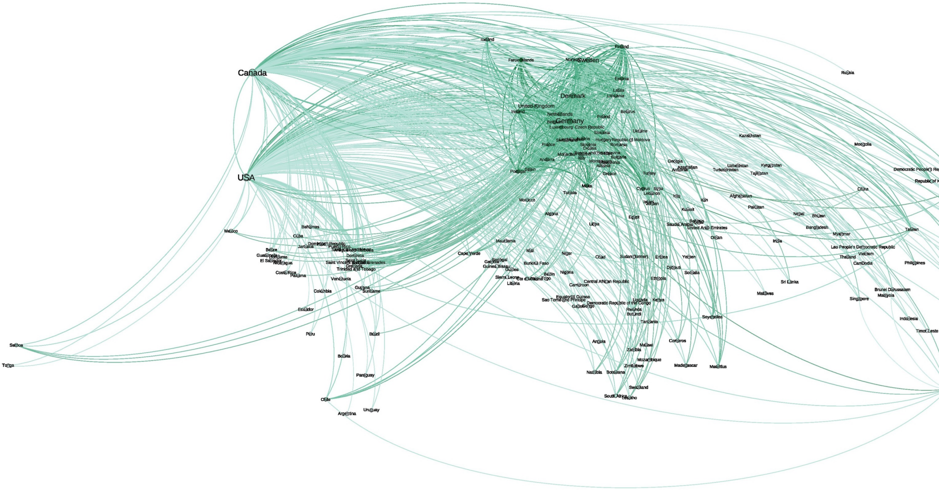
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Ecuador
Peru
Brazil
Bolivia
Paraguay
Chile
Argentina
Uruguay
Samoa
Tonga
Mauritania
Cape Verde
Mali
Niger
Chad
Sudan (former)
Eritrea
Yemen
Djibouti
Somalia
Senegal
Gambia
Guinea-Bissau
Guinea
Burkina Faso
Benin
Nigeria
Sierra Leone
Liberia
Togo
Central African Republic
Cameroon
Ethiopia
Equatorial Guinea
Sao Tome and Principe
Democratic Republic of the Congo
Gabon
Congo
Uganda
Kenya
Rwanda
Burundi
Tanzania
Seychelles
Angola
Comoros
Malawi
Zambia
Mozambique
Zimbabwe
Madagascar
Mauritius
Namibia
Botswana
Swaziland
South Africa
Lesotho

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- The length of cascades: 4-20 years
- Analysis of extensive margin: 94 countries have installed at least one wind turbine
- 195 nodes and 34 time periods

Challenges

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  Use maximum likelihood to estimate the parameters that maximise the probability to obtain the observed technology cascades.

Method (Gomez Rodriguez et al., 2010; Wu et al., 2013)

- Epidemiological approach: diffusion process explained by country characteristics.
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- Assume the cascades are independent, the likelihood of the set of observed cascades is

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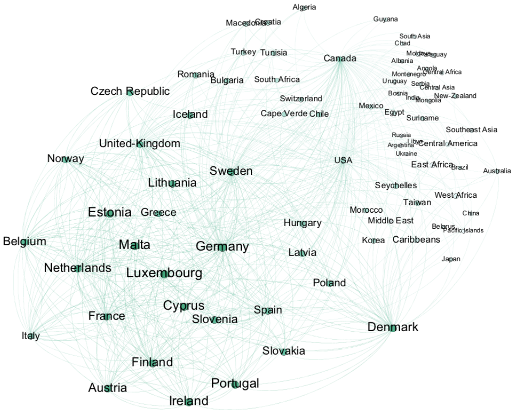
link variables:
- Geographic proximity
- Economic integration agreements
- International environmental agreements (Kyoto Protocol)

Results

The structure of the technological diffusion network:



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- Apart from in Europe, connections within regional clusters are weak.
- Can show which country pairs a technology should be "seeded" in to speed up technology diffusion.
- Comparison with CDM data:
  Actual diffusion is more evenly spread (not only China, India, or Brazil).

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- Technological capability: strong impact from a source country perspective.

Conclusions & policy implications

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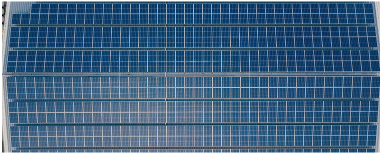
Conclusions & policy implications

- This research proposes to bridge the technology diffusion and the network formation literatures.
- Shows the important role of link characteristics for the diffusion of wind technology, in particular economic integration agreements.
- Smaller role of unilateral environmental support policy on the extensive margin.
- Technology diffusion a key element in climate clubs. (Nordhaus, 2015; Keohane and Victor, 2016)

Other applications



Thank you!

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Method (Gomez Rodriguez et al., 2010; Wu et al., 2013)

$$a_{i,j} = P_{(\alpha,\beta,\gamma)}(x_i, y_j, z_{i,j}) := \frac{1}{1 + e^{-(\alpha \cdot x_i + \beta \cdot y_j + \gamma \cdot z_{(i,j)})}}$$

- The diffusion of technology is captured by a ‘cascade" , i.e., a series of dates $(t_1, \cdots, t_N)$
  where t_i is the date at which the technological vintage was adopted in country i.
- Such a cascade can also be represented by a binary matrix of adoption status $S_v \in \{0, 1\}^{N \times T}$
  where $S_v(i, t) = 1$ if the vintage v is present in country i at time t and $S_v(i, t) = 0$ otherwise.

Method

The probability for a non-adopting country j to remain non-adopting in period $t+1$ is

$$\prod_{\{i|S_v(i,t)=1\}} (1 - P_{(\alpha,\beta,\gamma)}(x_i^t, y_j^t, z_{i,j}^t))$$

The probability that the country adopts is

$$1 - \prod_{\{i|S_v(i,t)=1\}} (1 - P_{(\alpha,\beta,\gamma)}(x_i^t, y_j^t, z_{i,j}^t))$$

Method

The probability of the transition from the adoption vector $S_v(\cdot, t)$ to the adoption vector $S_v(\cdot, t+1)$ is given by:

$$\prod_{\{j|S_v(j,t+1)=0\}} \prod_{\{i|S_v(i,t)=1\}} (1 - P_{(\alpha,\beta,\gamma)}(x_i^t, y_j^t, z_{i,j}^t))\times$$
$$\prod_{\{j|S_v(j,t+1)=1\}} \left(1 - \prod_{\{i|S_v(i,t)=1\}} (1 - P_{(\alpha,\beta,\gamma)}(x_i^t, y_j^t, z_{i,j}^t))\right) \qquad (1)$$

The likelihood of cascade S_v is:

$$\mathcal{P}^v_{(\alpha,\beta,\gamma)}(X, Y, Z) = \prod_{t=0}^{T-1} \prod_{\{j|S_v(j,t+1)=0\}} \prod_{\{i|S_v(i,t)=1\}} (1 - P_{(\alpha,\beta,\gamma)}(x_i^t, y_j^t, z_{i,j}^t))\times$$
$$\prod_{t=0}^{T-1} \prod_{\{j|S_v(j,t+1)=1\}} \left(1 - \prod_{\{i|S_v(i,t)=1\}} (1 - P_{(\alpha,\beta,\gamma)}(x_i^t, y_j^t, z_{i,j}^t))\right) \qquad (2)$$

Method

Assume the cascades are independent, the likelihood of the set of observed cascades is

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Convex programming problem solved using the algorithm NETRATE

(Gomez-Rodriguez et al., 2010, 2011)

Results

Maximum likelihood estimations ($N = 195, T = 34$)

Link variables:	Effect	Significant?
Geographical proximity	+	
Economic Integration Agreements	+	YES
Kyoto ratification	-	YES
Unilateral variables:		
Rule of law (target country)	+	YES
Wind generation (source country)	+	YES
ArCo (source country)	+	YES
ArCo (target country)	-	
RE direct policy (source country)	+	YES
RE direct policy (target country)	-	
RE tariff exemptions wind (target country)	+	

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Geographical distance not an obstacle for wind technology diffusion.
(cf. Chaney, 2014; Ferrier et al., 2016)