Transforming Energy Systems: Economics, Policies and Change

Steven Fries
Institute for New Economic Thinking
University of Oxford

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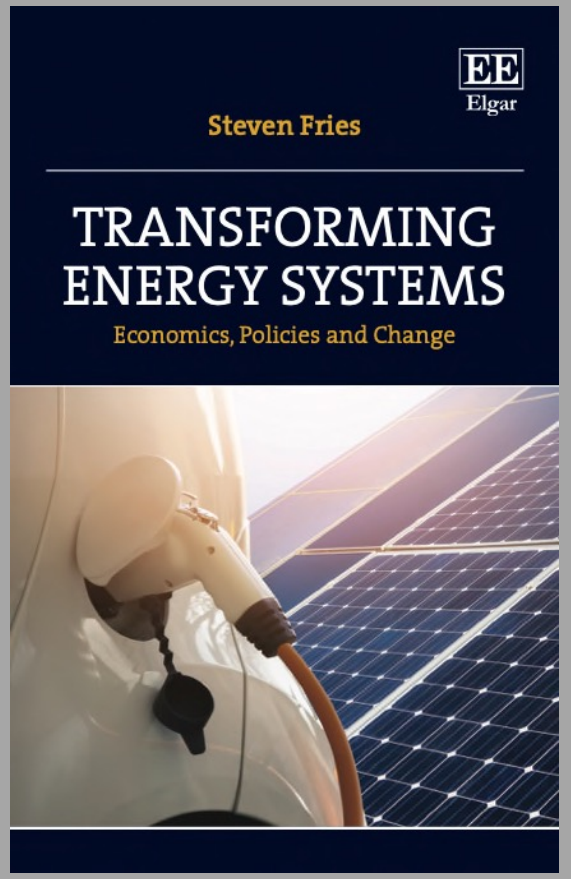


Societal climate goals and energy

- **Net-zero emissions (NZE) of CO_2 necessary to stabilize the climate**
  - By mid-century to limit average temperature change to 1.5ºC
- **Current energy systems rely on thermal technologies and fossil resources**
  - Energy supply technologies—extraction, power generation, refining and fuels
  - Energy end-use technologies—transport, buildings, industry
  - Capital stock value of end-use technologies > supply technologies x 10
- **Low-carbon systems would use mostly renewable and nuclear resources**
- **Electrification, low-carbon fuels / end-use technologies, carbon management**

How to orchestrate change?

- **Markets—2 market failures and 2 policy fixes**
  - Climate externality and emissions pricing
  - Knowledge spillovers from innovation and government R&D supports
- **Yes—but this is only part of the story—key parts missing**
  - Significant dynamic external economies in transforming energy systems
  - Major distributional impacts of change and risk of time-inconsistent policies
  - Energy market institutions and infrastructures must adapt to low carbon
- **2 policy fixes alone are insufficient to advance low-carbon alternatives**

Heterodox approach to change

R&D supports; ‘market-creating’ industrial policies for low-carbon; commit to NZE by sector

Direct investments in innovation and market creation toward low-carbon

Goal-consistent emissions pricing guides capital stock toward climate goals

Knowledge spillovers and pathways

- **Social returns to investments in innovation > private returns**
- **Spillovers from low-carbon advances like those from other new technologies**
  - Quality-adjusted, low-carbon patent citations similar in scope to ICT patents (Dechezleprêtre et al., 2017)
  - Few highly cited low-carbon patents account for most forward citations
- **Cumulative and path-dependent nature of knowledge about technologies**
  - Firms more likely to engage in low-carbon innovation if engaged in past related innovations or exposed to low-carbon innovations in home markets
  - Electric drive trains, renewable generation, energy storage (Noailly and Smeets, 2015; Aghion et al., 2016; Lazkano et al. 2017)

Dynamic external economies

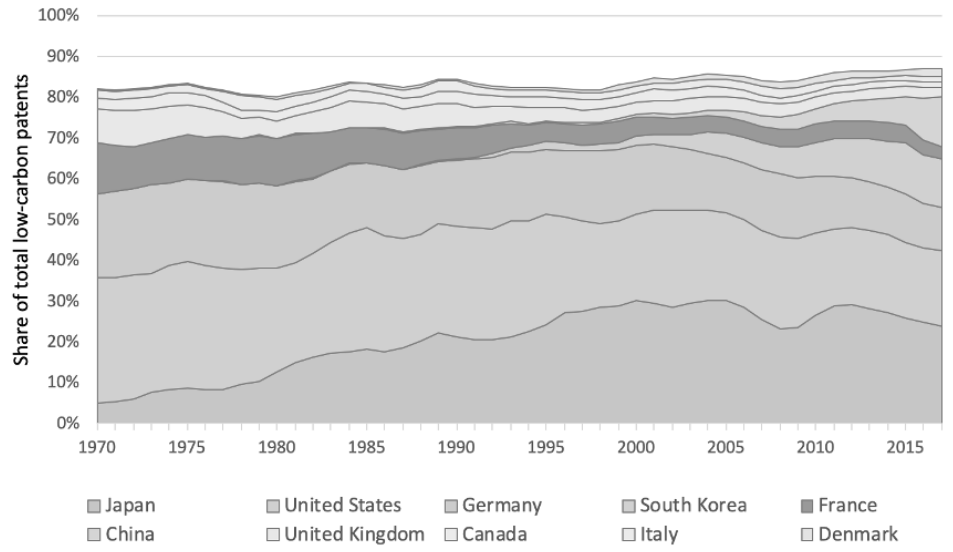
- **Early movers create ‘assets’ that benefit followers and decline with scale**
  - They can be, e.g., selling externalities or better skill pools / supply chains
- **Shared infrastructure also lower costs, but must adapt to low carbon**
- **Energy systems and network effects of shared infrastructure**
  - ‘Lock in’ of incumbent technologies (Arthur, 1989; Seto et al., 2016)
  - For example, high ‘switching costs’ for early adopters of electric vehicles (EV)
  - Policy supports for early EV adopters / initial charging networks, Li et al. (2017)
  - Switching costs decline with deployment; costs of not switching rise

Incentives for innovation and market creation

- **Market returns to investments in innovation and market creation**
  - Product differentiation in some markets—autos (higher powered incentive)
  - Emissions pricing / scarcity pricing in others—electric power (lower powered incentive)
- **Public R&D spending and private R&D investments supported by tax credits**
  - Private R&D directed by changes in profitability and policies (Acemoglu, 2002)
- **Market-creating policies for low-carbon alternatives**
  - Dynamic external economies—network effects and external scale economies
  - Limited credibility of early emissions pricing commitments; builds low-carbon interests

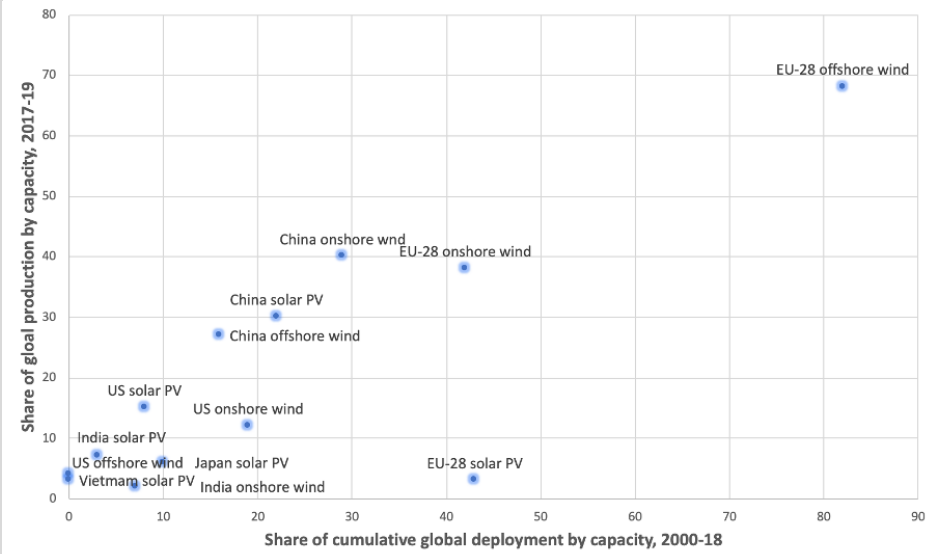
Early movers in low-carbon technologies

Country shares of lower carbon technology patents (% total)



Sources: European Patent Office, PATSTAT Worldwide Patent database. Data analysis by Vivid Economics.

Renewables deployment (2000-18) and manufacturing shares (2017-19) (%)



Sources: International Renewable Energy Agency and Bloomberg New Energy Finance.

- ❑ Countries that specialize in innovation in general also specialize in low-carbon
- ❑ Early deployment of wind / solar PV correlates with manufacturing specialization
- ❑ Market-creating policy supports (~$2tn resource cost) and home-country effects

Emissions pricing impacts and thresholds

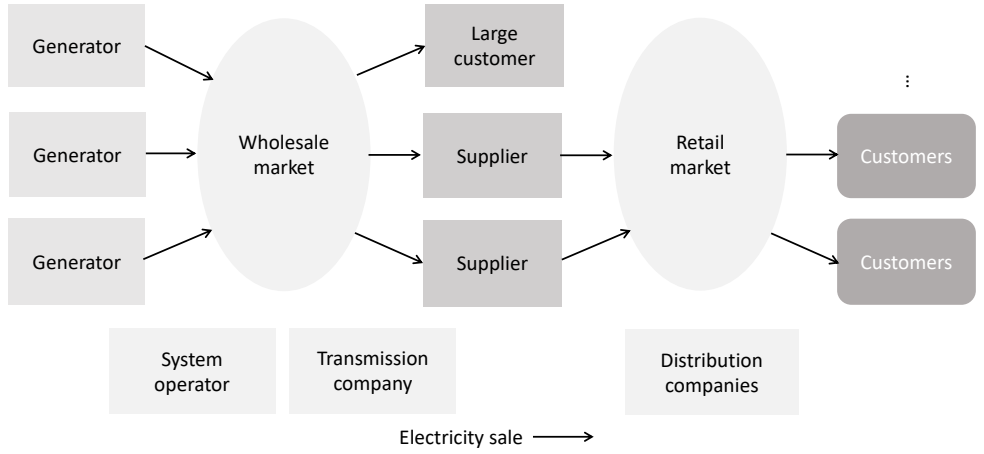
- **Economy-wide emissions price sets the marginal cost of emissions**
  - Raises the relative price of emission-intensive goods and services
  - Reduces demand, profits and capacity in these sectors
- **Also has significant regressive distributional impacts**
  - High emission-intensive expenditure shares in low-income budgets
  - Displaced coal mining communities and hysteresis effects
- **‘Shadow-costs’ of binding future NZE constraints vary across sectors**
  - ‘Easy-to-decarbonize’ sectors—much of power, surface transport, buildings
  - ‘Hard-to-decarbonize’ sectors—aviation and shipping, heavy industry (materials)

Two ways to calibrate emissions pricing

- **Cost-effective emissions tax consistent with climate goals / NZE constraints**
  - Present value of predictable, future shadow costs of NZE constraints
  - Transparent; aligns with NZE goals and market-creating ‘industrial’ policies
  - Calibrated by easy- and hard-to-decarbonize sectors
- **Economy-wide emissions tax = social cost of carbon**
  - Depends on modelled long-run climate change damages and mitigation costs
  - Wide uncertainty ranges; value judgements on equity weights and discount rates
  - Tax rate cuts for households and businesses; carbon ‘dividends’
- **Choice criteria: credible expectations anchor; efficiency; distributional fairness**

Electricity market designs and trade-offs

Competitive wholesale and retail electricity markets



Adapted from: Hunt (2002, pp. 42–7) and Kirschen and Strbac (2019, pp. 2–7).

- Control of market power in tight markets v. efficient investment in capacity and reliability
- Power prices in tight markets key to capacity investments but ‘missing money’ concerns
- Long-term power contracts long a feature of wholesale power markets
- Capacity remuneration converts uncertain scarcity prices into fixed capacity payments
- Credibility of electricity market design and emissions pricing key to low-carbon power
- Designs must also be adapted to low-carbon technologies and their characteristics

Heterodox energy reform strategies

- **Clear climate goals – timebound NZE commitments by sector**
- **Comprehensive domestic energy reforms**
  - Support for R&D and market-creation for low-carbon alternatives (early movers)
  - Promote product differentiation of low-carbon offerings
  - Cost-effective emissions pricing in line with NZE goals, differentiated by sector
  - Adapt government-designed electricity markets and energy infrastructures
- **Sequenced to build low-carbon interests and policy credibility**
- **Distributional impacts adequately addressed to ease resistance to change**
- **Vital to instill higher powered incentives to advance low-carbon alternatives**

THANK YOU