The Role of Government Policies in Renewable Energy

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Expert Dialogue on Subsidy Reform
June 18, 2024

Outline

Renewable Sector Overview

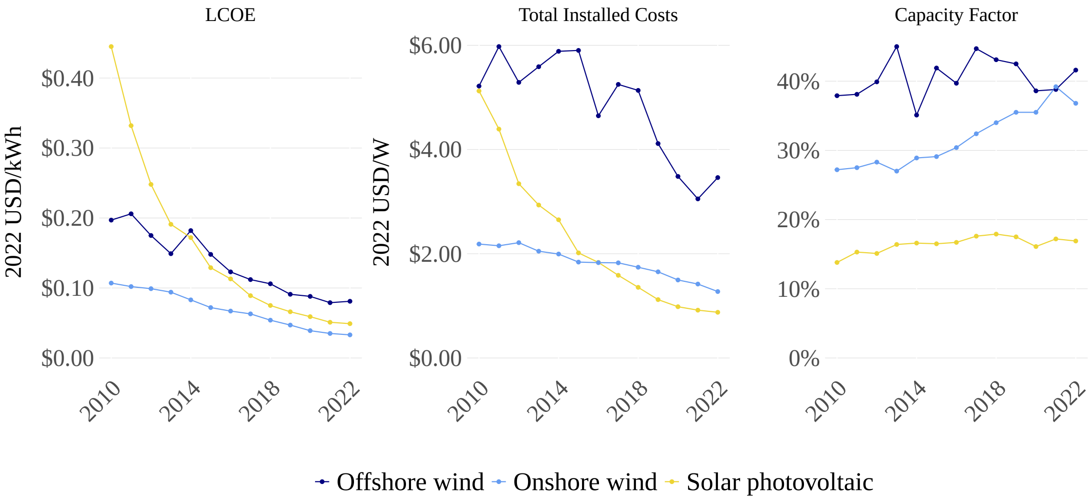
Industrial Policies in Use for Renewable Energy

Economic Rationales for Subsidies and Tariffs

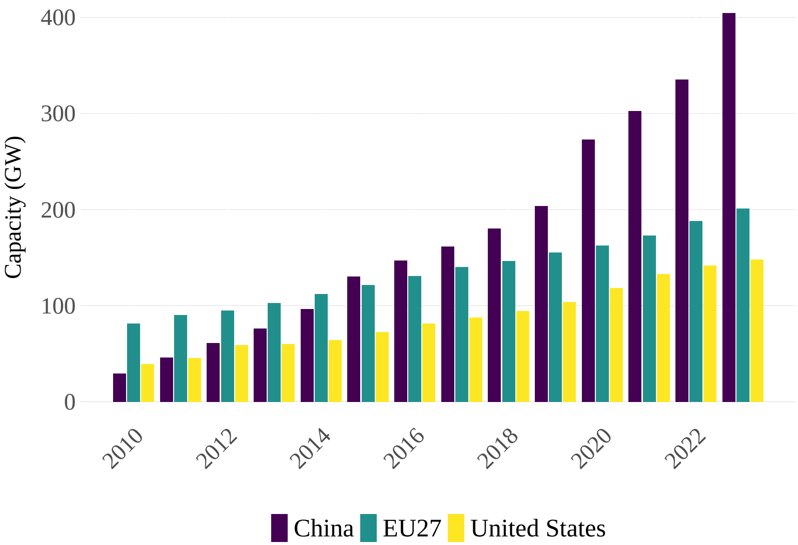
Third-Party Effects

Research Gaps and Discussion

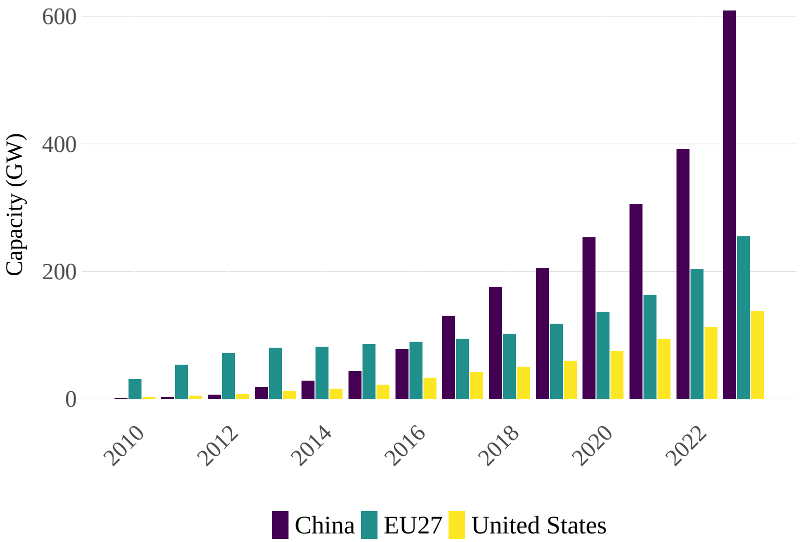
Global LCOE, Capacity Factor, and Total Installed Costs



Trends in Adoption - Onshore Wind: Cumulative Capacity



Trends in Adoption - Solar: Cumulative Capacity



Market Structure and Trade - Wind

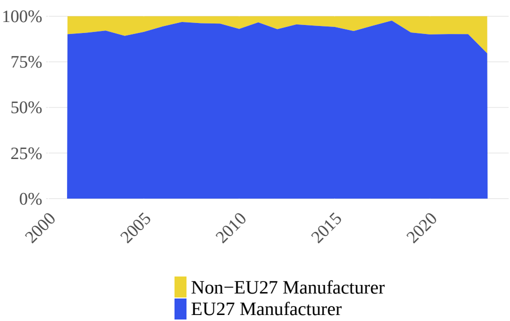
- Wind markets are dominated by a small number of manufacturers
  - Europe: Enercon, Vestas, and Siemens Gamesa
  - US: GE, Vestas, and Siemens Gamesa

- EU wind turbines are almost exclusively manufactured by European companies

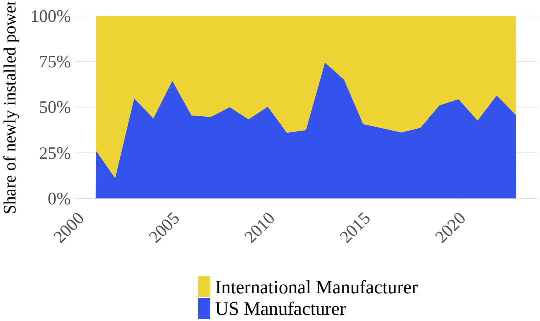
- US market is less dominated by US companies, though most manufacturing locations are within the US

- Imports play a smaller role than domestic production, in part due to transport costs

Manufacturer Origin - Wind Turbines

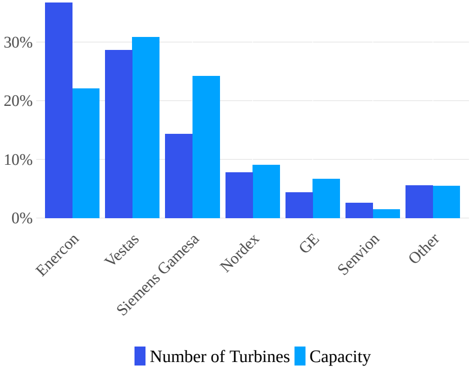


(a) European Union

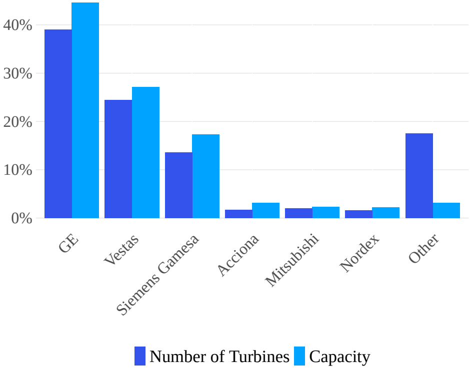


(b) United States

Manufacturer Market Shares - Wind



(a) European Union



(b) United States

Market Structure and Trade - Solar

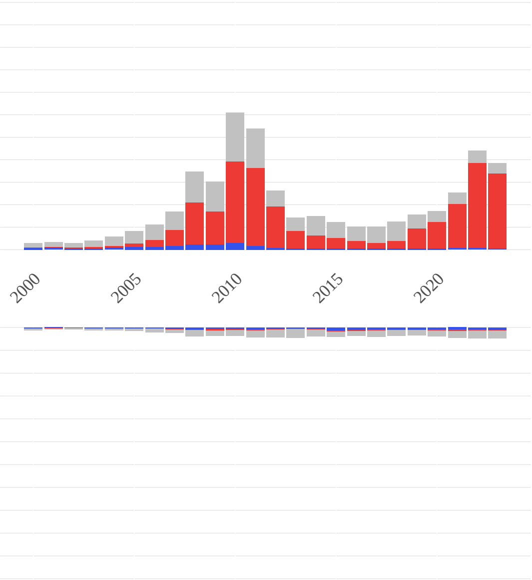
- Regional solar markets are less concentrated than wind, in part due to lower transport costs (but also differences in economies of scale)

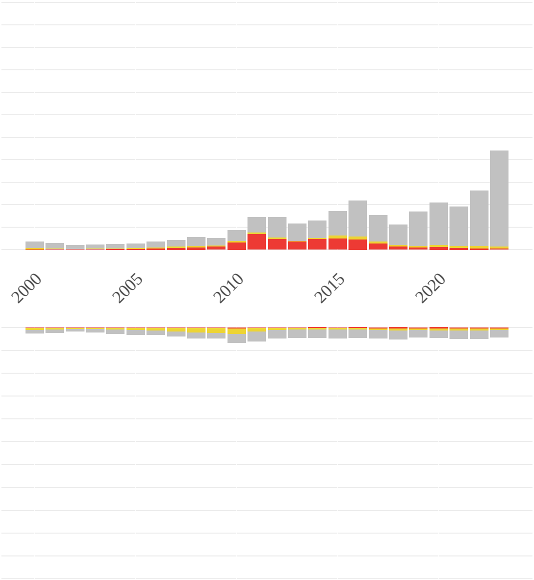
- China is the dominant manufacturer origin for solar panels

- US and EU manufacturing declined in the face of import competition from China

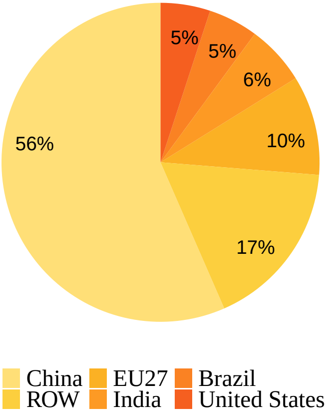
- US and EU imports influenced by comparative advantage and trade barriers

Import Flows over Time - Solar

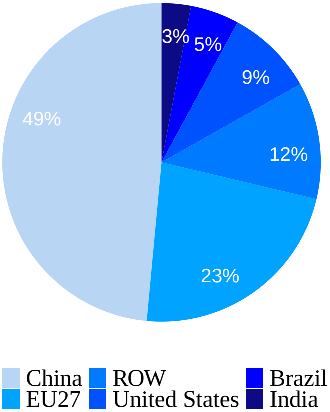




Employment in the Renewable Energy Sector (2021-2022)



(a) Solar (≈4.9 million jobs in total)



(b) Wind (≈1.4 million jobs in total)

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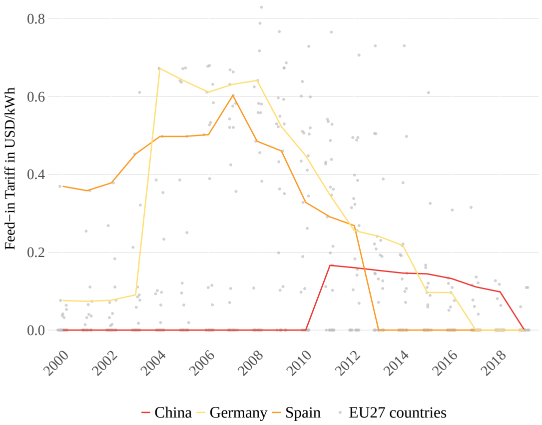
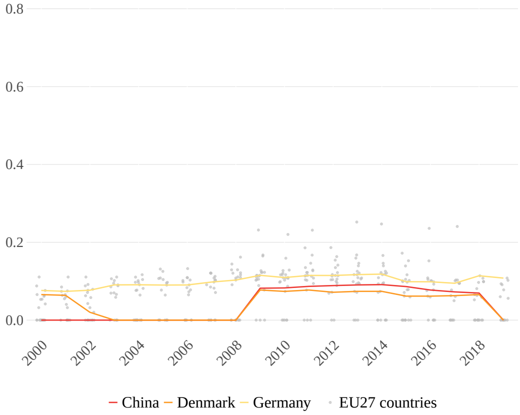
Overview of Government Policies for Renewable Energy

- Demand subsidies
  - Feed-in tariffs are the primary demand subsidy for EU countries, China, Japan, etc.
  - By contrast, the US primarily subsidizes investment and output through tax credits
  - US state and local subsidies primarily subsidize demand (not supply)
- Supply subsidies
  - China subsidizes renewable energy manufacturing (though difficult to quantify)
  - US now has domestic manufacturing subsidies under the Inflation Reduction Act
    - CRS projects this will be 1/3 of renewable tax spending over the next 5 years (big!)
    - But impacts are difficult to predict
- Barriers to trade
  - US and EU imposed tariffs on Chinese solar products
  - Some tariffs in wind, but they have played a smaller role

Demand Subsidies - Feed-in Tariffs



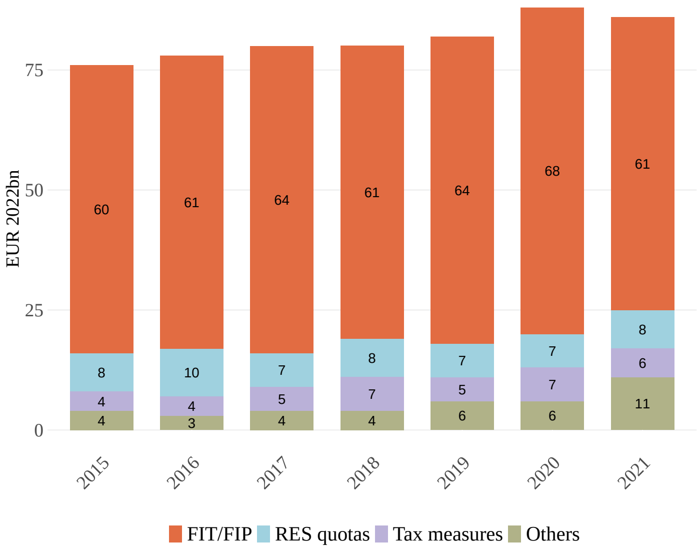
(a) Solar



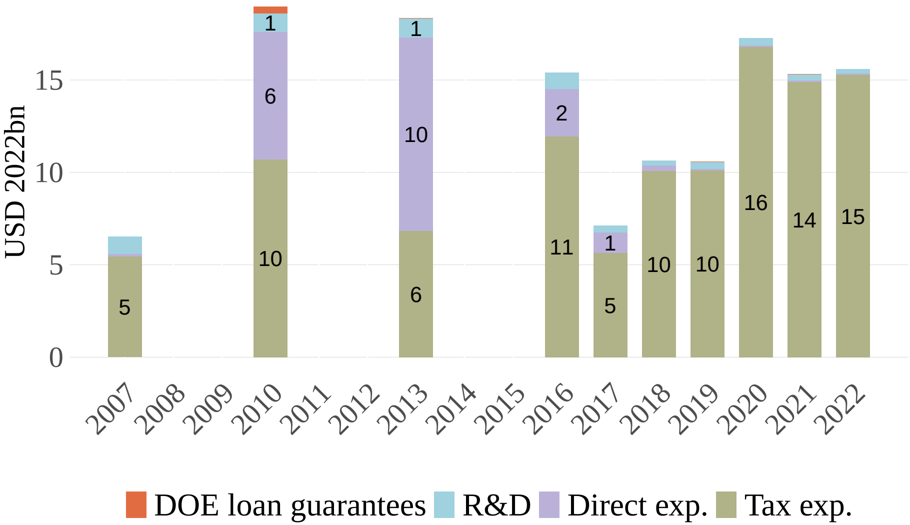
(b) Wind power

By contrast, the US offers a Production Tax Credit of \$0.0275 per kWh

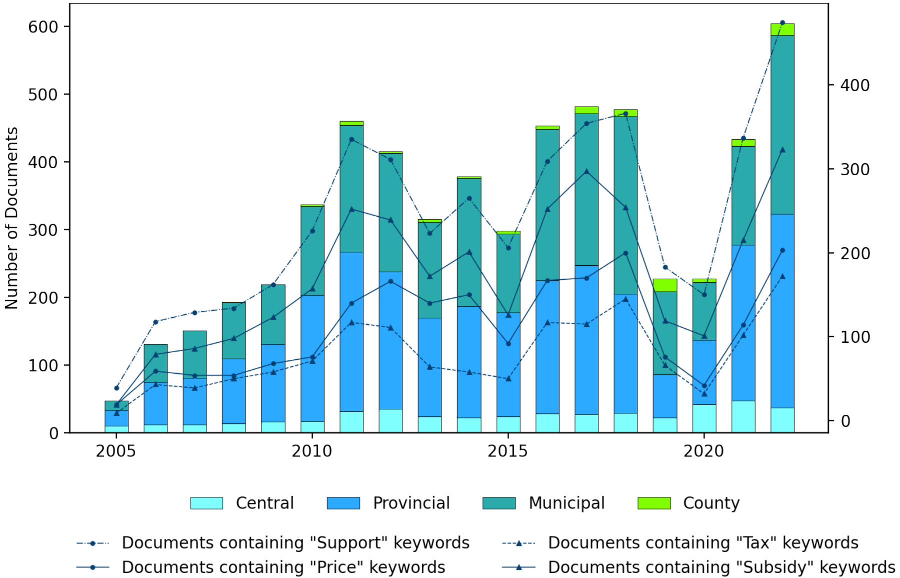
Demand Subsidies - by Instrument - EU27



Demand Subsidies - by Instrument - US (Federal)



Supply Subsidies - Wind - China



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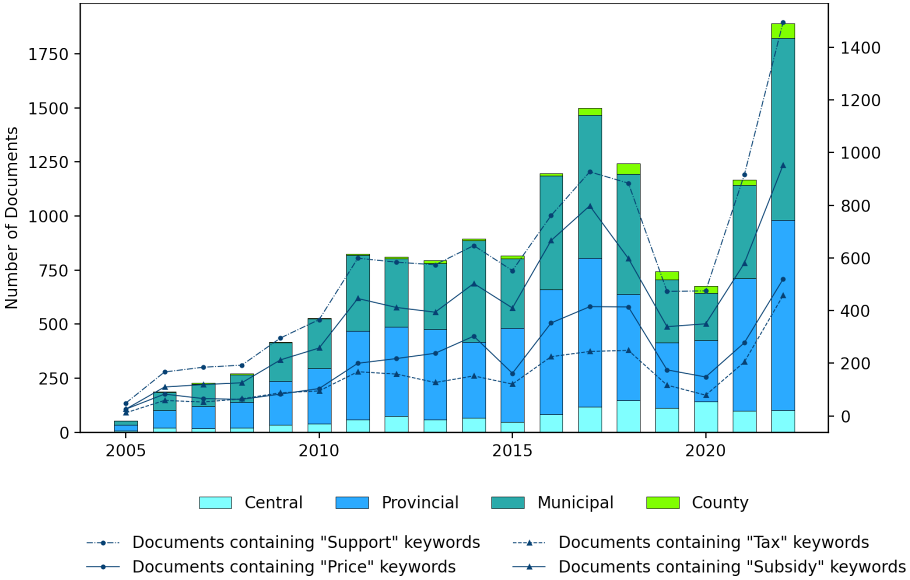
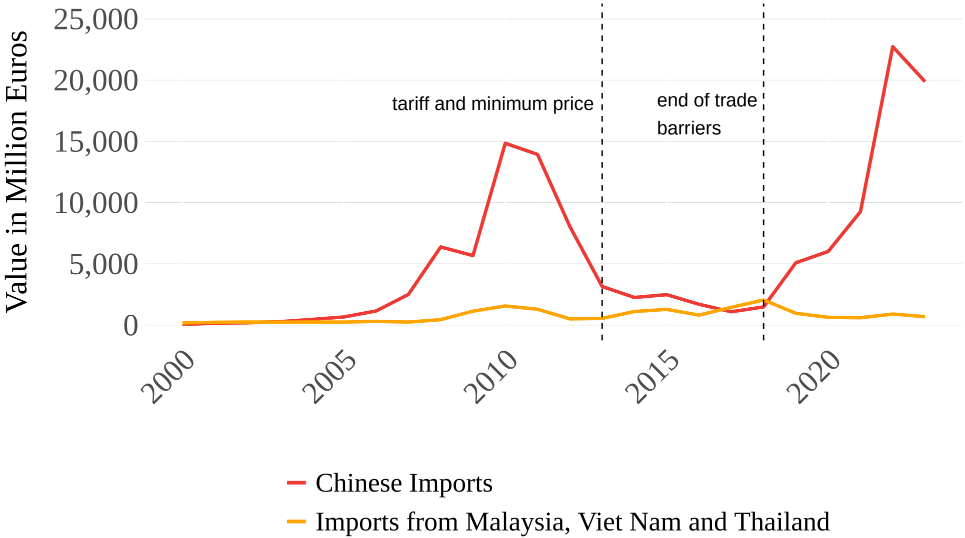
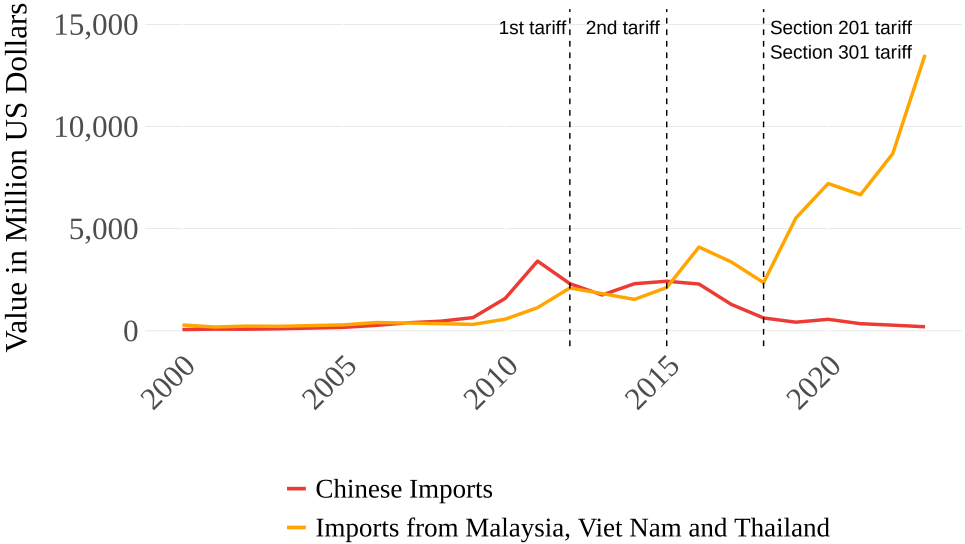


Barriers to Trade - Solar - EU



Barriers to Trade - Solar - US



Summary - Comparison between Wind and Solar

	Wind	Solar
Market structure	Concentrated	Fragmented
Technology	Large economies of scale LBD in size	More modular LBD in cells, installation
Labor market	Upfront, mostly non-local	Manufacturing and installation
Trade costs	Large, produced near site	Small, global supply chain
Demand subsidies	Utility-scale	Utility-scale and residential
Trade instruments	Limited interventions	Substantial interventions

Outline

Demand Subsidies - Second-Best Environmental Policy

- Stated purpose of many demand subsidies is to correct environmental externalities

- Efficiency impacts of subsidies depend on their level and targeting
  - The pollution offset by renewable energy varies over space and time, and national subsidies are generally uniform subsidies to output or investment

- Studies in the US and European contexts find that demand subsidies are net beneficial on environmental grounds based on current estimates of the SCC (e.g., Cullen, 2013; Abrell et al., 2019)
  - Caveat: prior evidence is mixed and context-dependent

Demand Subsidies - Other Rationales

- Industry-level experience curve arguments

- Specific market failures:
  - Learning-by-doing spillovers
  - Innovation spillovers
  - Adoption frictions (e.g., information asymmetry, inattention, etc.)

Supply Subsidies

- Can be rationalized on similar basis as demand subsidies: environmental externalities, knowledge spillovers, etc.

- International competition and imperfect competition can introduce strategic interactions that provide additional policy rationales for individual countries:
  - Profit shifting incentives (Brander and Spencer, 1985)
  - Infant industry protection (Harrison and Rodríguez-Clare, 2009)
  - Energy security

Barriers to Trade

- Since import tariffs raise consumer prices for renewable energy, they are difficult to justify on environmental grounds

- Traditional economic rationale is terms-of-trade: tariff revenue could raise domestic welfare if tariff pass-through is incomplete
  - For renewables, preexisting distortion of environmental externalities appears to dominate (Bollinger et al., 2024; Houde and Wang, 2023)

- Theoretical underpinning for trade barriers seems weak unless there are significant dynamic scale economies for domestic production

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Third-Party Effects

- Government policies for renewable energy can have international spillover effects through several channels:
  - **Environmental externalities**
  - Profit shifting and consumer surplus impacts
  - Innovation spillovers
  - Learning-by-doing
  - Scale and agglomeration economies

- While our primary focus is on international spillovers, we necessarily rely also on evidence from domestic analyses

Demand Subsidies - Spillovers from Innovation (Gerarden, 2023)

- Dynamic effects of demand subsidies and other industrial policy can have first-order impacts on the overall evolution of the industry

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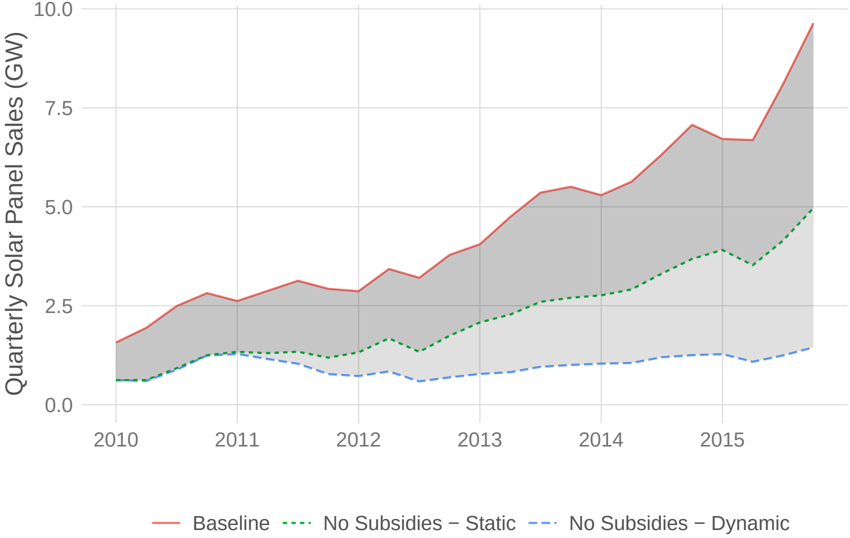

Demand Subsidies - Spillovers from Innovation (Gerarden, 2023)

- Dynamic effects of demand subsidies and other industrial policy can have first-order impacts on the overall evolution of the industry

- Subsidies in one country can have spillover effects on other countries
  - Increased demand $\Rightarrow$ induced innovation by global manufacturers $\Rightarrow$ lower prices, higher quantities in third countries
  - Innovation induced by German feed-in tariffs generated cross-country positive spillovers in form of consumer surplus gains and improved environmental quality

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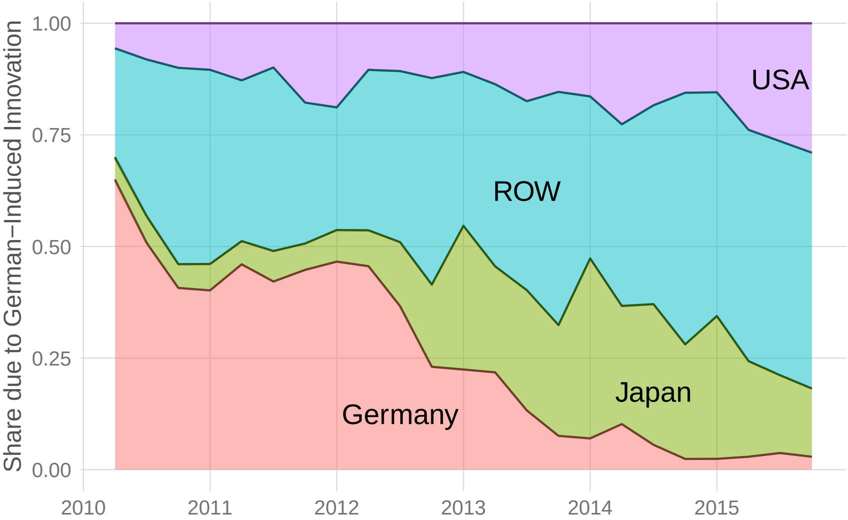

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- Caveat: this analysis does not comprehensively evaluate efficiency implications
  - Quantifying innovation spillovers across firms remains an open question

Demand Subsidies - Spillovers from Learning-by-Doing

- Demand subsidies' effects on learning could generate social surplus by bringing future environmental benefits to the present (private vs social discount rates)

- Demand subsidies could be justified as a second-best instrument to address **non-appropriable** learning
    - Local learning-by-doing spillovers in wind and solar installation (Bradt, 2024; Bollinger and Gillingham, 2019; Anderson et al., 2019)
    - Global spillovers in wind turbine manufacturing (Covert and Sweeney, 2024): Chinese firms entering in the late 2000s benefited from prior experience of non-Chinese firms

Supply Subsidies - Spillovers from Production and Innovation

- Much less research on producer subsidies due to measurement challenges
- Banares-Sanchez et al. (2023) find solar manufacturing and innovation subsidies caused increases in production, innovation, and productivity for firms in China
  - Changes in production likely caused static third-party spillovers to other countries (positive for consumers and the environment and negative for competing firms)
  - Innovation could have spillovers, but more research is needed
  - Research design compares cities, does not imply aggregate effects
- Bollinger et al. (2024): a US manufacturing subsidy would have static spillovers:
  - Would decrease foreign manufacturing
  - Could increase or decrease profits for manufacturers from China
  - Would increase welfare due to presence of environmental externalities

Barriers to Trade - Spillovers from Production

- Bollinger et al. (2024) find US import tariffs on solar panels caused:
  - Chinese firms to shift manufacturing to other countries, causing spillover effects on production, employment, and profits in multiple countries
  - Less adoption of solar panels in the US, which reduced domestic and global welfare (and had spillover effects through environmental externalities)

- In the wind market, Coşar et al. (2015) find eliminating frictions between Denmark and Germany would increase total welfare in both countries

- Other, dynamic spillovers from trade barriers are an open research question

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Research Gaps

- More work is needed to construct a comprehensive understanding of the producer subsidies used to promote renewable energy manufacturing activity and how they vary over space and time

- While there is some evidence on the effects of specific instruments (primarily demand subsidies) on learning and innovation, prior work has not determined when one policy tool is more effective than another

- Challenging to assess infant industry arguments and other dynamic externalities due to limited empirical evidence
    - Reliance on structural models due to limited policy variation and equilibrium effects

Discussion: Towards Policy Recommendations

- Despite protectionist measures, the renewable sector is a success story with dramatic industry-level LBD, consumer benefits, and reductions in GHG emissions

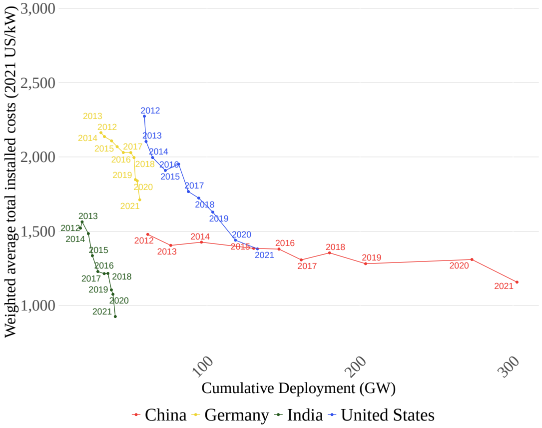
- Compared to other industries, subsidies abroad have generated benefits to importing countries through cheaper power, downstream jobs, and less pollution

- Batteries as a complement to renewable generation: still considering potential synergies in innovation spillovers and trade between them

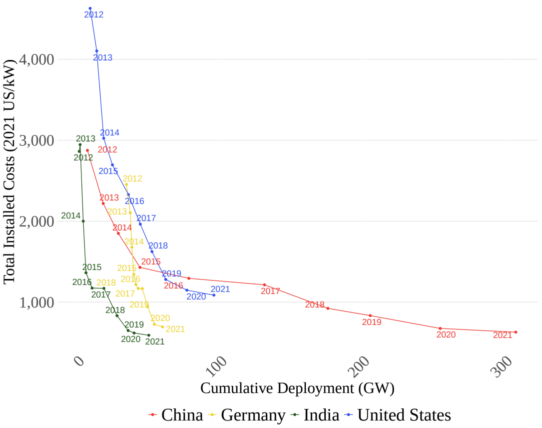
- Security of supply not the focus of the study so far: not a major issue due to the build-up of stock $\rightarrow$ focus on recycling capacity

Appendix

Industry-Level Experience Curves for Solar and Wind Power

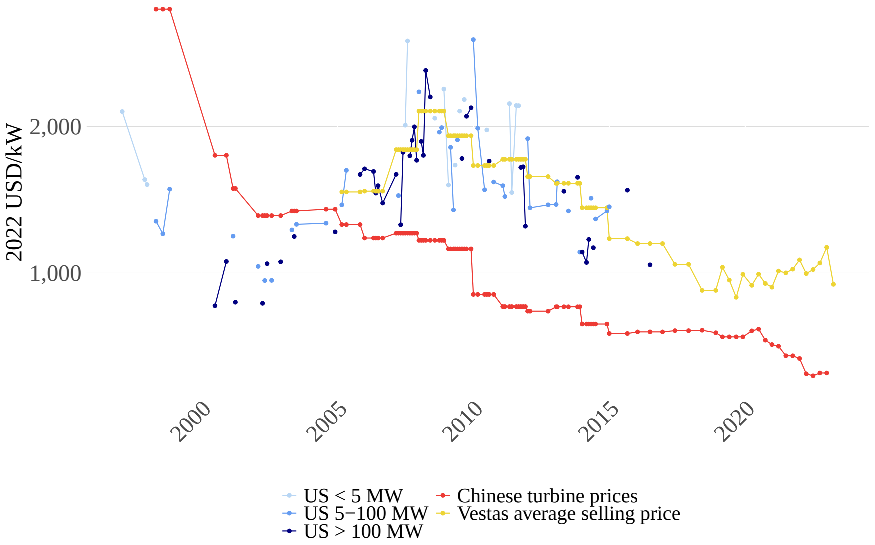


(a) Onshore wind



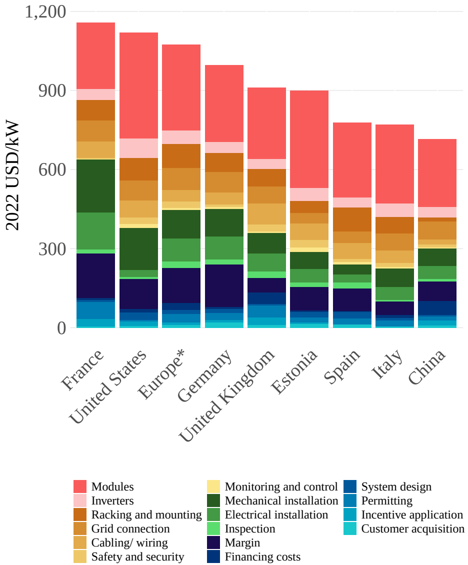
(b) Solar photovoltaic

Trends in Wind Turbine Prices



Breakdown of Utility-Scale Solar Installed Costs (2022)

- Variation in installed costs stems from variation in underlying cost drivers
- Highest hardware costs in the US, lowest in China
- Very low installation costs in Spain
- Lower costs in China mostly attributable to low hardware and installation costs



Trends in Costs - Summary

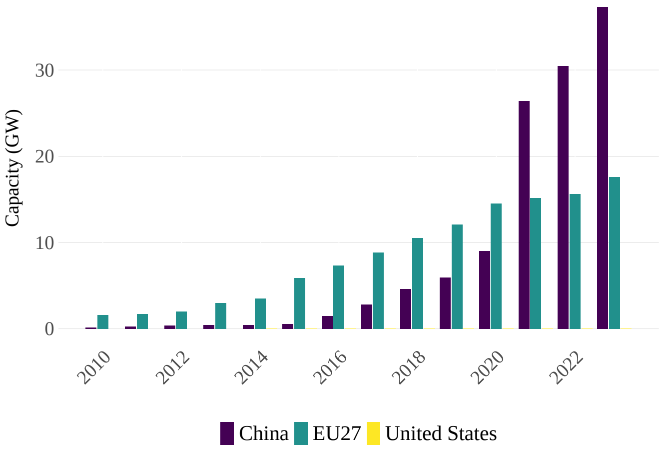
- Globally, total installed costs of solar PV and wind have decreased significantly
- Factors contributing to secular cost reductions:
  - Industry-level experience effects (R&D, LBD, economies of scale, etc.)
  - Financial support schemes
  - Increasing demand
- Factors contributing to cost fluctuations:
  - Supply chain bottle necks
  - High commodity prices
  - High interest rates
- Capacity factor increased, strongest increase for onshore wind
- LCOE decreased, most significantly for solar

Trends in Adoption - Onshore Wind

- China has more installed onshore wind than the EU, the US, India combined (2023)
- Europe: despite record additions of onshore wind, EU is far off of its yearly deployment goals of around 33 GW
- US: growth in onshore wind has slowed down in recent years
- Potential barriers to wind deployment:
  - High interest rates and inflation
  - Supply chain issues
  - Local opposition
  - Lengthy permitting processes
  - Grid integration

Trends in Adoption - Offshore Wind

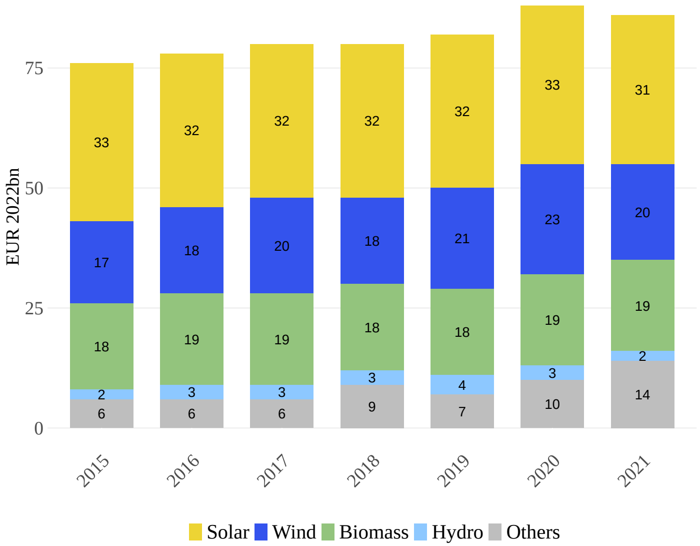
- Offshore wind capacity is an order of magnitude smaller than onshore
- China overtook UK's position as global leader in offshore wind capacity in 2021
- More than 50% of offshore capacity is located in China
- Offshore market in the US is more nascent, though Biden administration goal of 30 GW offshore by 2030



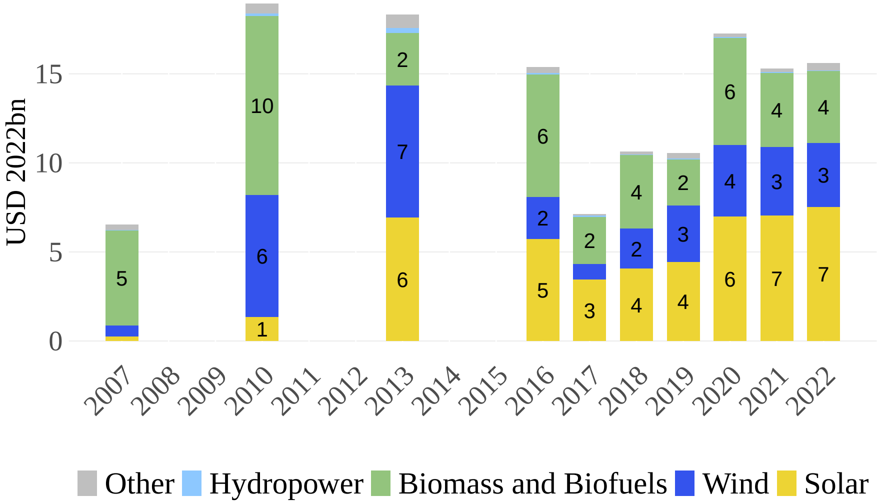
Trends in Adoption - Solar

- Solar capacity is growing more rapidly than wind in the EU, the US, and China
- China significantly accelerated deployment in recent years
- Installed capacity per capita is higher in the EU and the US compared to China
- Potential barriers to solar deployment:
  - High interest rates and inflation
  - Decrease in investments in Europe
  - Trade disputes

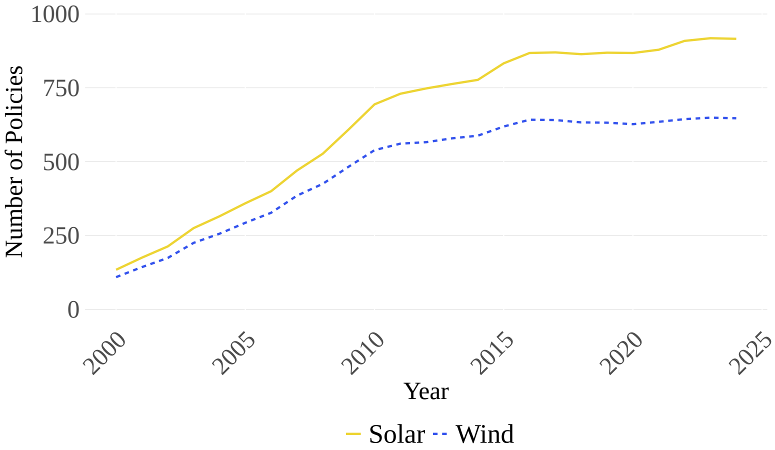
Renewable Subsidies by Technology of EU27



United States Subsidies Expenditures by Technology



United States State and Local Subsidies by Technology



United States State and Local Subsidies by Type

Program Type	2010	2020
Loan Program	76	109
Grant Program	84	102
Rebate Program	82	98
Property Tax Incentive	51	65
Net Metering	53	60
Interconnection	56	59
Renewables Portfolio Standard	45	51
Sales Tax Incentive	32	40
Industry Recruitment/Support	38	37
Other	183	253

(a) Solar

Program Type	2010	2020
Grant Program	67	82
Loan Program	58	73
Net Metering	53	60
Interconnection	54	57
Property Tax Incentive	47	57
Renewables Portfolio Standard	46	52
Industry Recruitment/Support	40	40
Sales Tax Incentive	27	30
Rebate Program	27	27
Other	123	155

(b) Wind