The Case for Growth: Threats and Opportunities

EEA Special Session on Productivity and Innovation
August 25th, 2022

John Van Reenen

LSE and MIT

Summary

- World faces severe **growth threats** arising from Pandemic & Ukraine crises.
- Even before these crises, there was global problem of **low productivity growth** since (at least) the 2008-9 Financial Crisis
- Opportunity for policy framework to focus on equitable and environmentally **sustainable growth**
- **Innovation and Diffusion** of better *technologies* and *management practices* are key

- We know much about *what* to do. Main challenge is political *will*
  - Need to join up in new **Marshall Growth Plan**
  - Frame around missions on **climate, defense & health**

OUTLINE OF TALK

Threats and Opportunities

Productivity

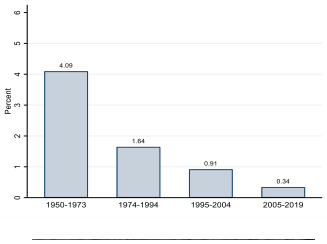
Climate Change

Defense

Health

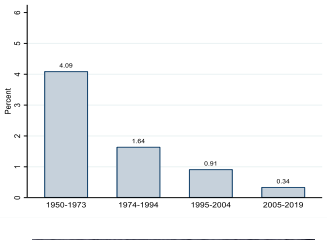
The Political Challenge

Threats and Opportunities (with examples!)



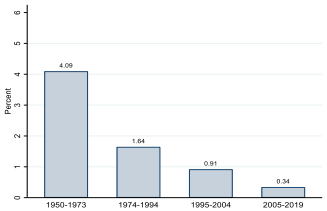
Threats	Examples
Long-run productivity Slowdown	Post Global Financial Crisis

Threats and Opportunities (with examples!)



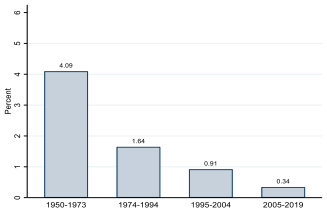
Threats	Examples	Opportunities	Examples
Long-run productivity Slowdown	Post Global Financial Crisis	New Marshall Plan for Growth	“Lightbulb” Policy Toolkits

Threats and Opportunities (with examples!)



Threats	Examples	Opportunities	Examples
Long-run productivity Slowdown	Post Global Financial Crisis	New Marshall Plan for Growth	“Lightbulb” Policy Toolkits
Environment	Climate Change		

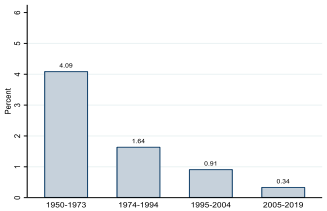
Threats and Opportunities (with examples!)



Threats	Examples	Opportunities	Examples
Long-run productivity Slowdown	Post Global Financial Crisis	New Marshall Plan for Growth	“Lightbulb” Policy Toolkits
Environment	Climate Change	Directed Clean Technical Change	**Solar** 

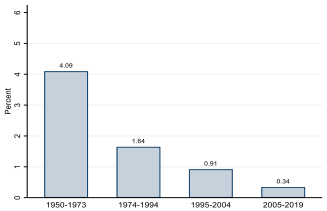
Threats and Opportunities (with examples!)

Threats	Examples	Opportunities	Examples
Long-run productivity Slowdown	Post Global Financial Crisis	New Marshall Plan for Growth	“Lightbulb” Policy Toolkits
Environment	Climate Change	Directed Clean Technical Change	Solar
Defense	Ukraine		



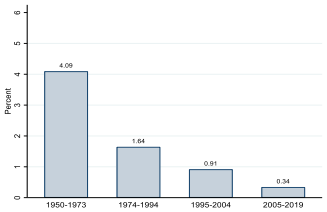
Threats and Opportunities (with examples!)

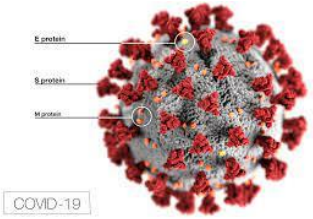
Threats	Examples	Opportunities	Examples
Long-run productivity Slowdown	Post Global Financial Crisis	New Marshall Plan for Growth	“Lightbulb” Policy Toolkits
Environment	Climate Change	Directed Clean Technical Change	Solar
Defense	Ukraine	Spillovers from Military Innovation	DARPA/Open



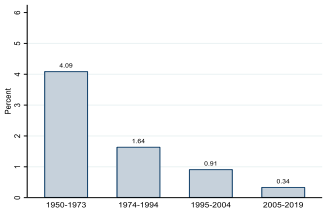
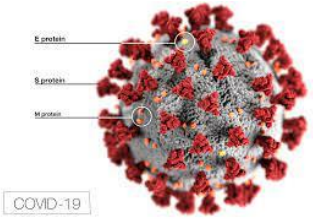
Threats and Opportunities (with examples!)

Threats	Examples	Opportunities	Examples
Long-run productivity Slowdown	Post Global Financial Crisis	New Marshall Plan for Growth	“Lightbulb” Policy Toolkits
Environment	Climate Change	Directed Clean Technical Change	Solar
Defense	Ukraine	Spillovers from Military Innovation	DARPA/Open
Health	COVID-19		





Threats and Opportunities (with examples!)

	Threats	Examples	Opportunities	Examples
	Long-run productivity Slowdown	Post Global Financial Crisis	New Marshall Plan for Growth	Policy Toolkits
	Environment	Climate Change	Directed Clean Technical Change	Solar 
	Defense	Ukraine	Spillovers from Military Innovation	DARPA/Open
	Health	COVID-19	Public-Private partnerships	Vaccines, Electronic Health Records

OUTLINE OF TALK

Threats and Opportunities

Productivity

Climate Change

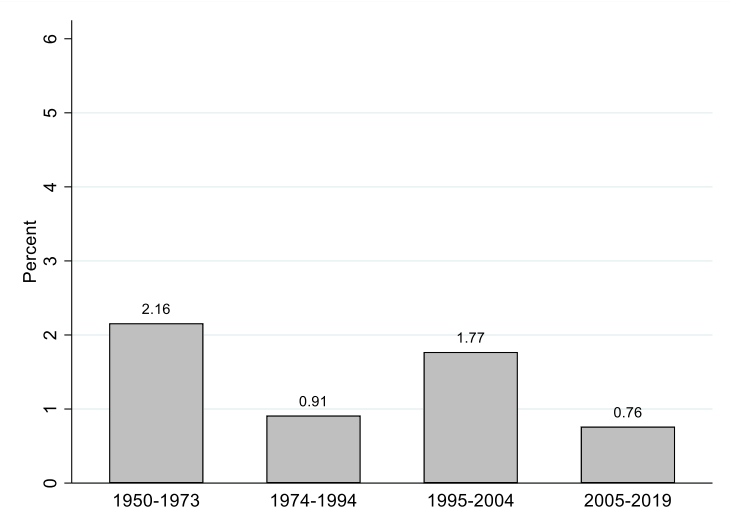
Defense

Health

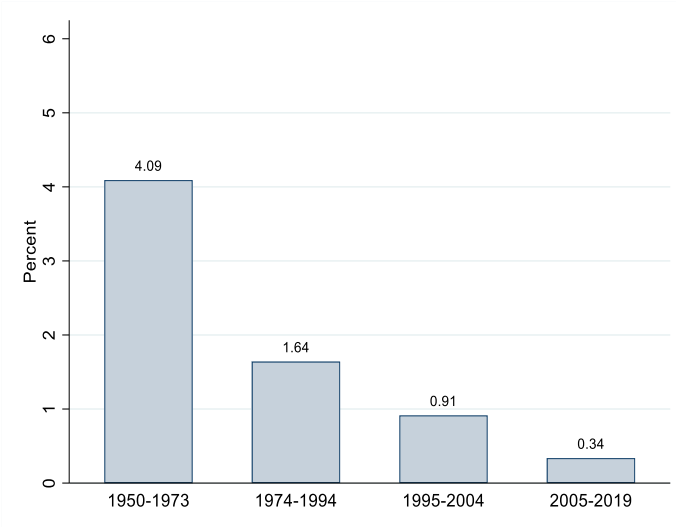
The Political Challenge

Productivity problems started long before COVID: Total Factor Productivity (TFP) growth 1950-2019: US, Euro-area and UK

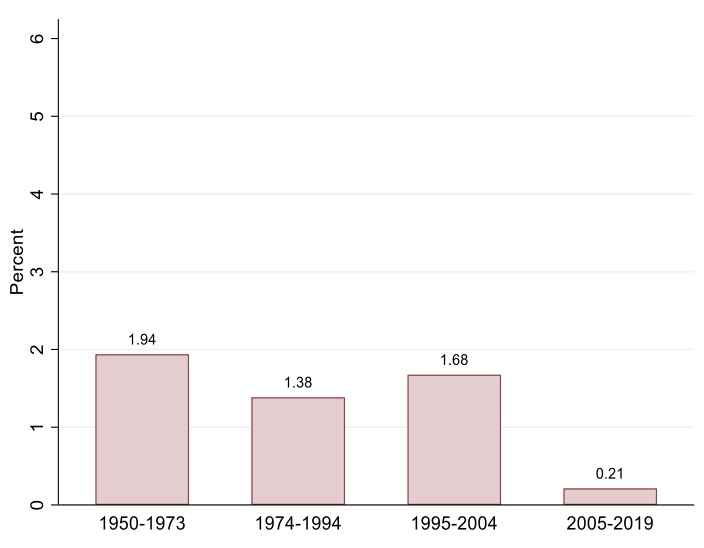
A. United States



B. Euro Area



C. United Kingdom



Source: Teichgraber & Van Reenen (2022) Updated data from Bergeaud, Cette, and Lecat (2016). Data publicly available at: http://www.longtermproductivity.com/

Notes: Average annual TFP growth in the US (panel A), Euro-area (panel B), and UK (panel C). Insufficient data for whole Euro-area so Germany, France, Italy, Spain, Netherlands, and Finland are used.

OUTLINE OF TALK

Threats and Opportunities

Productivity:

1. **Innovation Policies**
2. Diffusion Policies

Why should the government subsidize innovation?

- **Multiple market failures:**
  - Knowledge spillovers most important
  - Frictions in other markets (e.g. finance and SMEs)

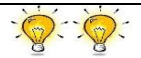
- **Empirical evidence suggests strong role for knowledge spillovers:**
  - Bloom, Shankerman & Van Reenen (2013); Lucking, Bloom and Van Reenen (2020); Jones & Summers (2022)
  - Social return to R&D is ~3-4 times as large as the private return. Implies large under-investment

Innovation Policy: The “Lightbulb” Table

(1)	(2)	(3)	(4)	(5)	(6)
Policy	**Quality of evidence**	**Conclusiveness of evidence**	**Benefit - Cost**	**Time frame:**	**Effect on inequality**

Source: Bloom, Van Reenen and Williams (2019, JEP)

Innovation Policy: The "Lightbulb" Table

(1) Policy	(2) Quality of evidence	(3) Conclusiveness of evidence	(4) Benefit - Cost	(5) Time frame:	(6) Effect on inequality
Direct R&D Grants	Medium	Medium		Medium-Run	↑
R&D tax credits	High	High		Short-Run	↑
Patent Box	Medium	Medium	Negative	n/a	↑

"Demand"

Source: Bloom, Van Reenen and Williams (2019, JEP)

Innovation Policy: The "Lightbulb" Table

(1) Policy	(2) Quality of evidence	(3) Conclusiveness of evidence	(4) Benefit - Cost	(5) Time frame:	(6) Effect on inequality
Direct R&D Grants	Medium	Medium	💡💡	Medium-Run	↑
R&D tax credits	High	High	💡💡💡	Short-Run	↑
Patent Box	Medium	Medium	Negative	n/a	↑
Skilled Immigration	High	High	💡💡💡	Short to Medium-Run	↓
Universities: incentives	Medium	Low	💡	Medium-Run	↑
Universities: STEM Supply	Medium	Medium	💡💡	Long-Run	↓
Exposure Policies	Medium	Low	💡💡	Long-run	↓
Trade and competition	High	Medium	💡💡	Medium-Run	↑

"Demand"

"Supply"

Source: Bloom, Van Reenen and Williams (2019, JEP)

Successful Innovation Policies

- **R&D tax credits (Come to 4pm session!)**
- Direct government grants
- Human capital supply
  - Expanding STEM workforce
  - Universities
  - Immigration
  - “Lost Einsteins”
- Competition and trade policy

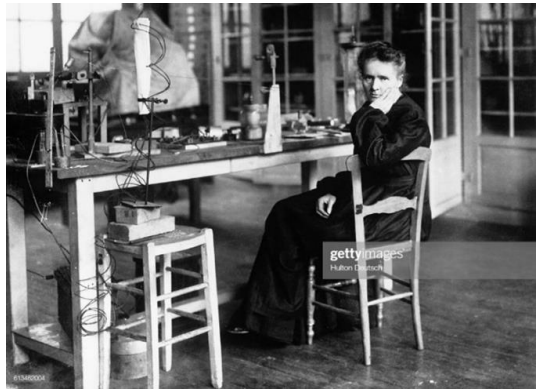
Successful Innovation Policies

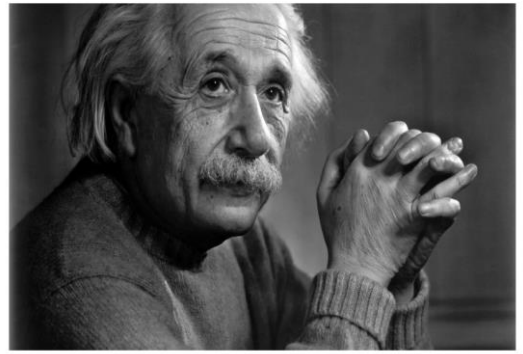
- **R&D tax credits (Come to 4pm session!)**
- **Direct government grants (later, example of defense)**
- Human capital supply
  - Expanding STEM workforce
  - Universities
  - Immigration
  - “Lost Einsteins”
- Competition and trade policy

Innovation Policies II: Human Capital

- R&D tax credits
- Direct government grants
- **Human capital supply**
  - Problem with tax and grants is that they subsidize *demand*. If supply side inelastic, the effect is to just drive up price of R&D (scientist wages) rather than volume of R&D
  - Increasing human capital more effective: directly increases innovation and reduces cost of R&D (reduces inequality)
- Competition and trade policy

Successful Innovation Policies II





- R&D tax credits
- Direct government grants
- **Human capital supply**
  - Expanding STEM workforce
  - Universities
  - Immigration
  - **“Lost Einsteins & Marie Curies”:** Few women, minorities & kids from low-income families in inventor pool = big loss of talent (Bell, Chetty, Jaravel, Petkova & Van Reenen, 2019a,b)
- Competition and trade policy

OUTLINE OF TALK

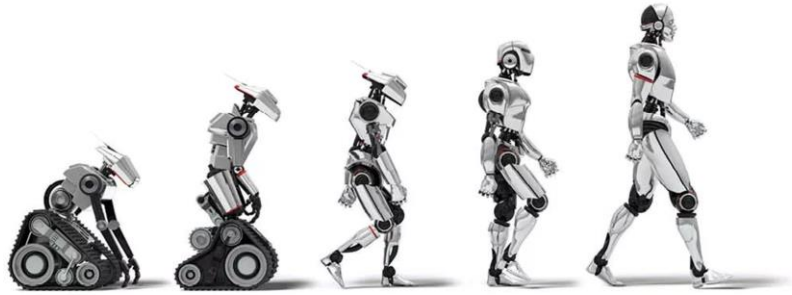
Threats and Opportunities

Productivity:

1. Innovation Policies
2. **Diffusion Policies**

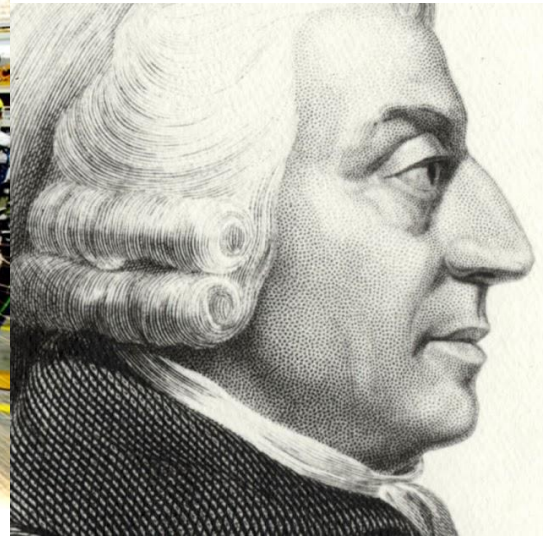
Two fundamental aspects of diffusion

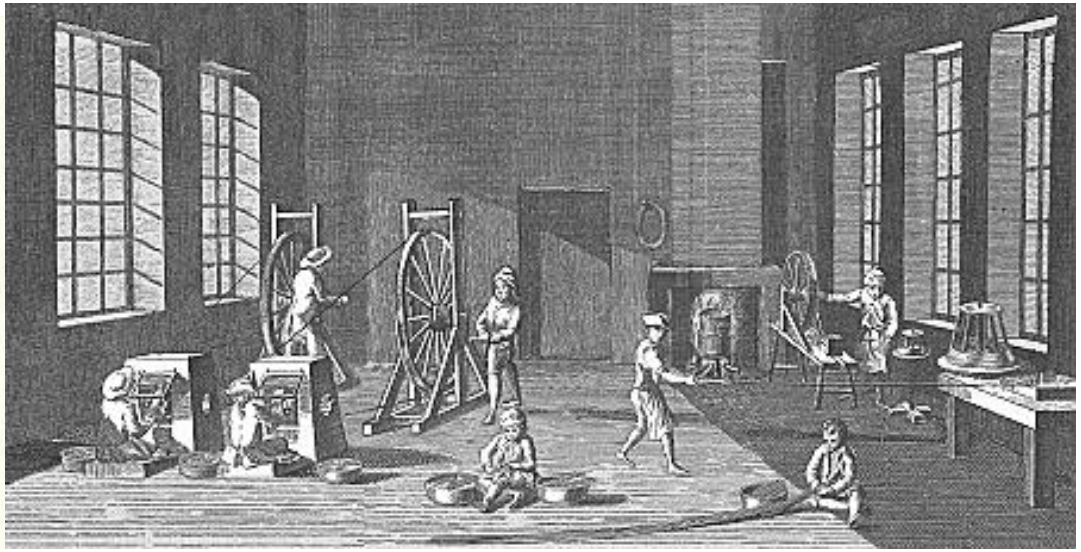
- **Technology**



- **Management practices**

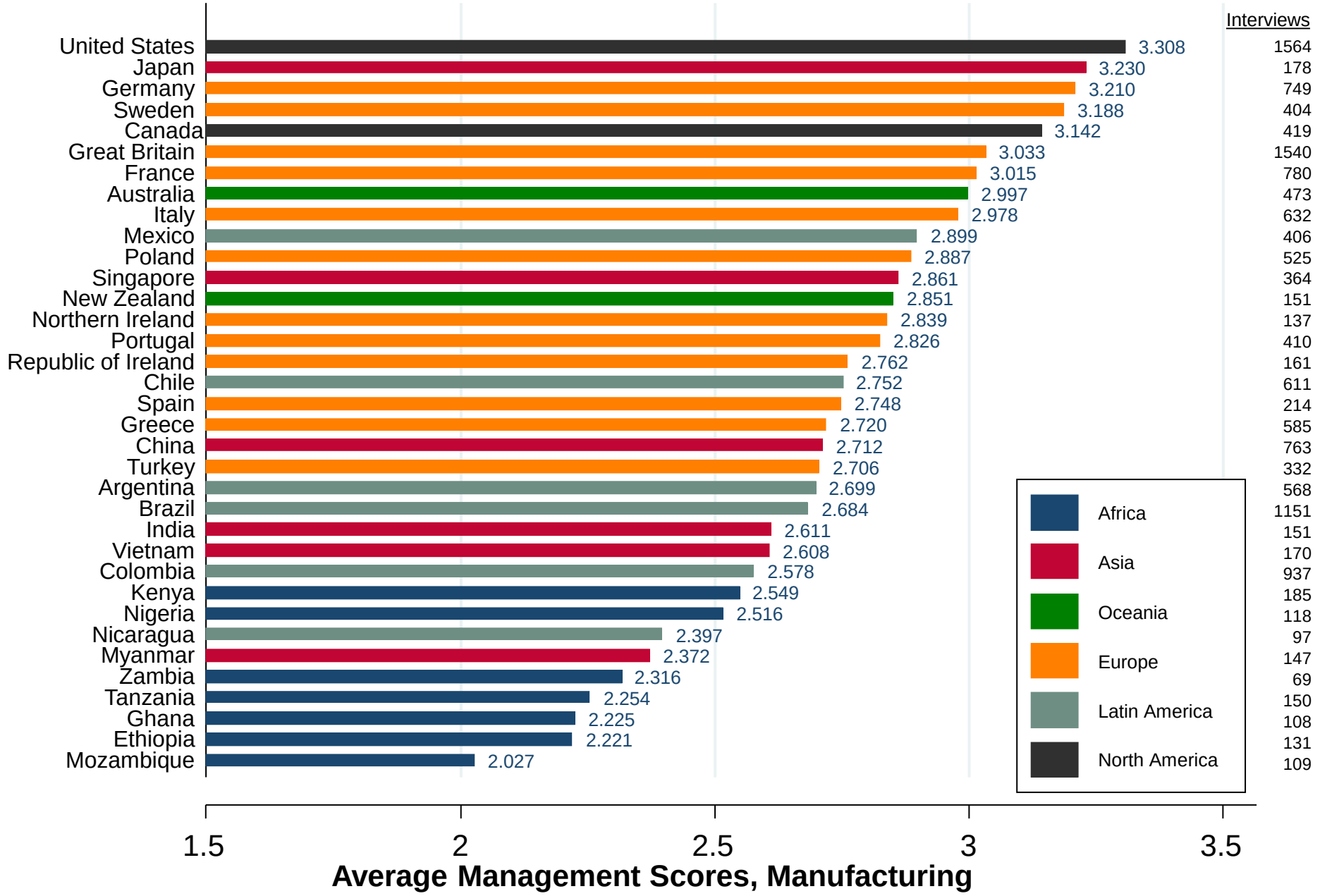
Toyota Plant





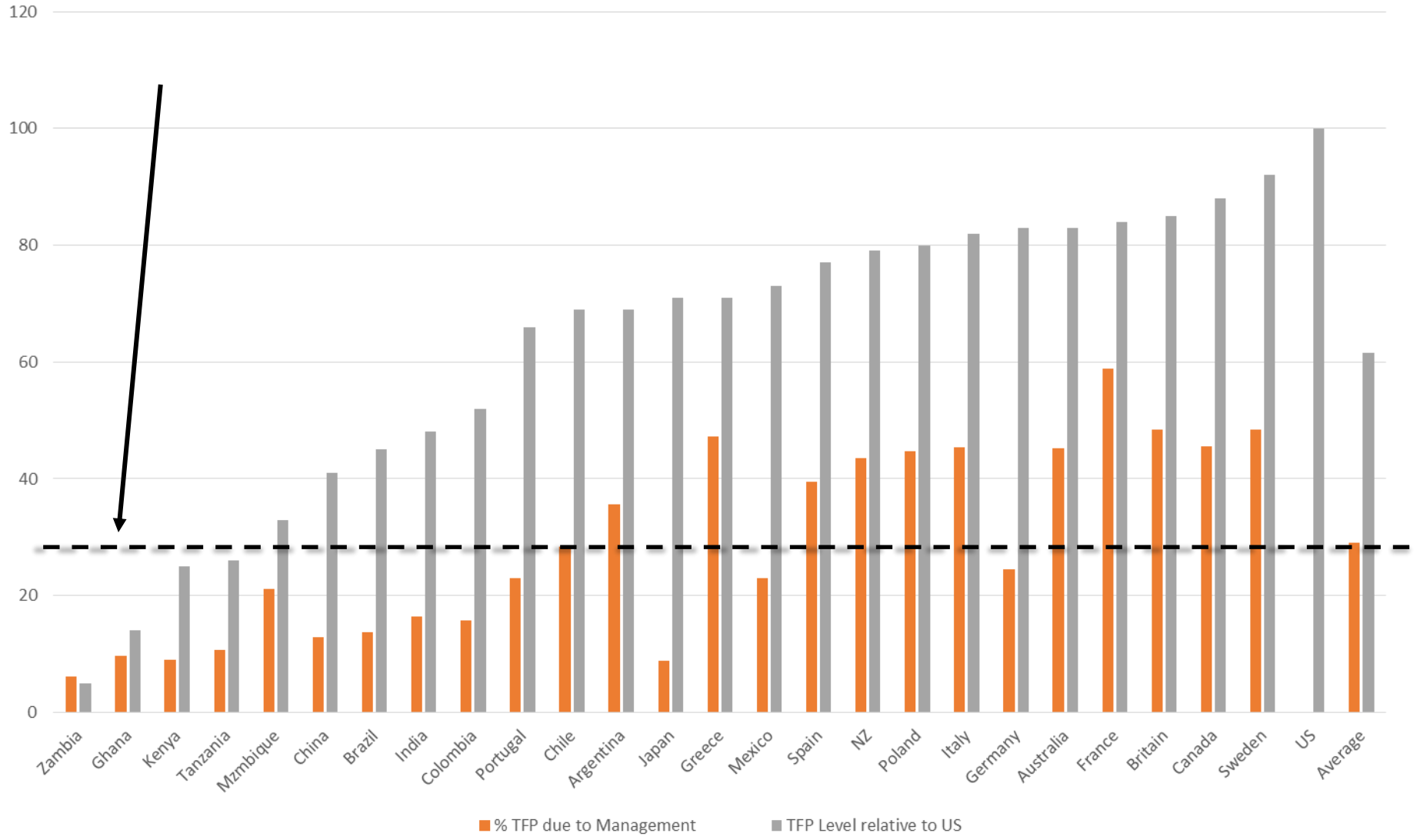
Adam Smith and the Pin Factory

Average Management Scores by Country



Source: Bloom, Sadun & Van Reenen (2020). **Note:** Unweighted average management scores; # interviews in right column (total = 15,489); all waves pooled (2004-2014)

Management accounts for about a third of cross-country TFP Gaps



Source: Bloom, Sadun, Schuh & Van Reenen “Management as a Technology” (2022)

Notes: TFP gaps from Penn World Tables;

Management policies Toolkit

L = Low; Not politically easy
M = medium
H = Highly possible

Policy type	Strength of evidence	Policy Net benefit (out of 5)	Difficulty of implementation	Time frame
Structural				
Competition	H		M	medium
Trade and FDI	H		L	medium
Education	M		M	long
Deregulation	M		L	medium
Governance	M		M/L	long
Direct				
Training - consulting	H		H	short
Training - formal classroom	M		H	medium
Information/benchmarking	L/M		H	medium

Source: Scur, Sadun, Van Reenen, Lemos & Bloom (2021)

OUTLINE OF TALK

Threats and Opportunities

Productivity

Climate Change

Defense

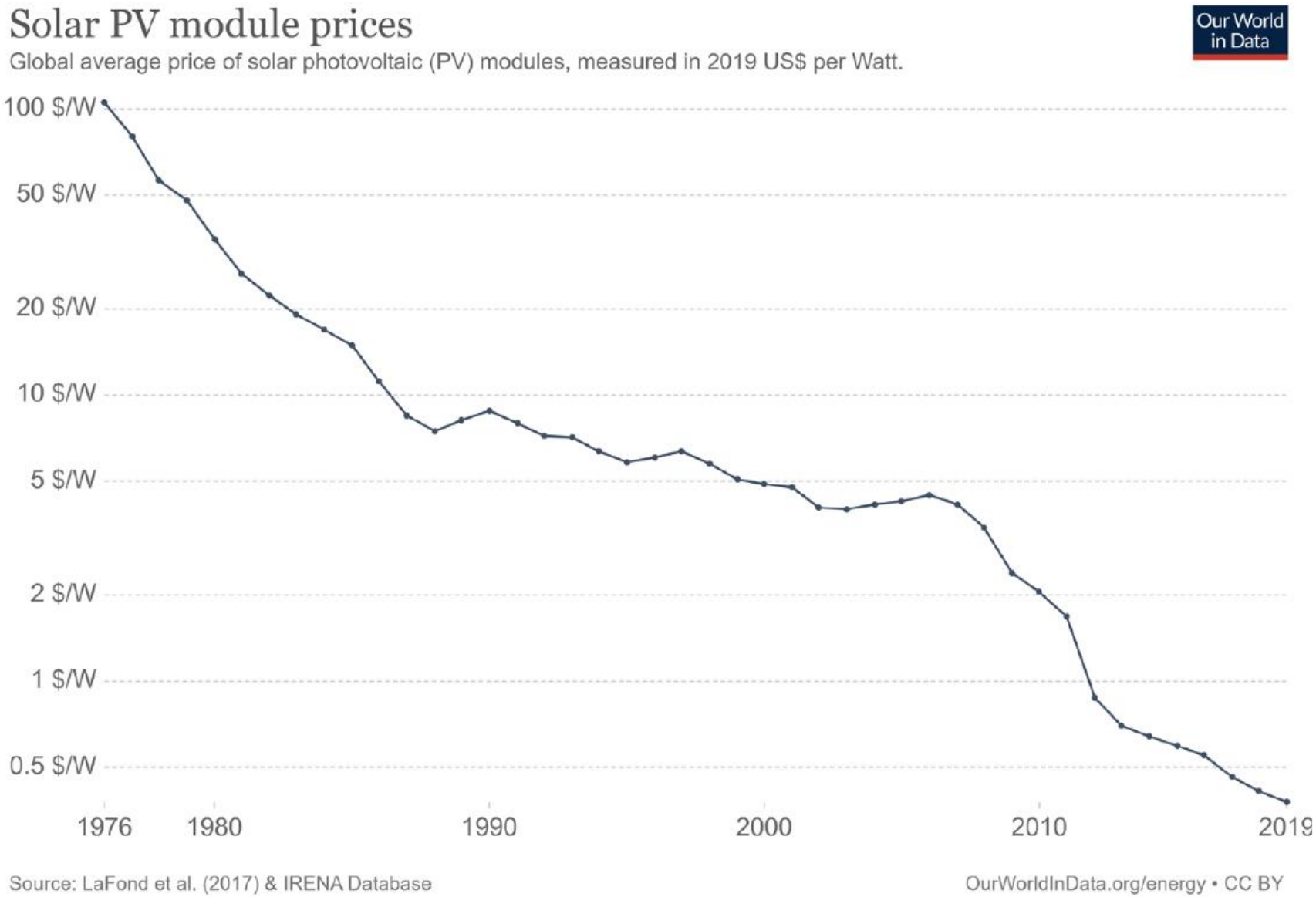
Health

The Political Challenge

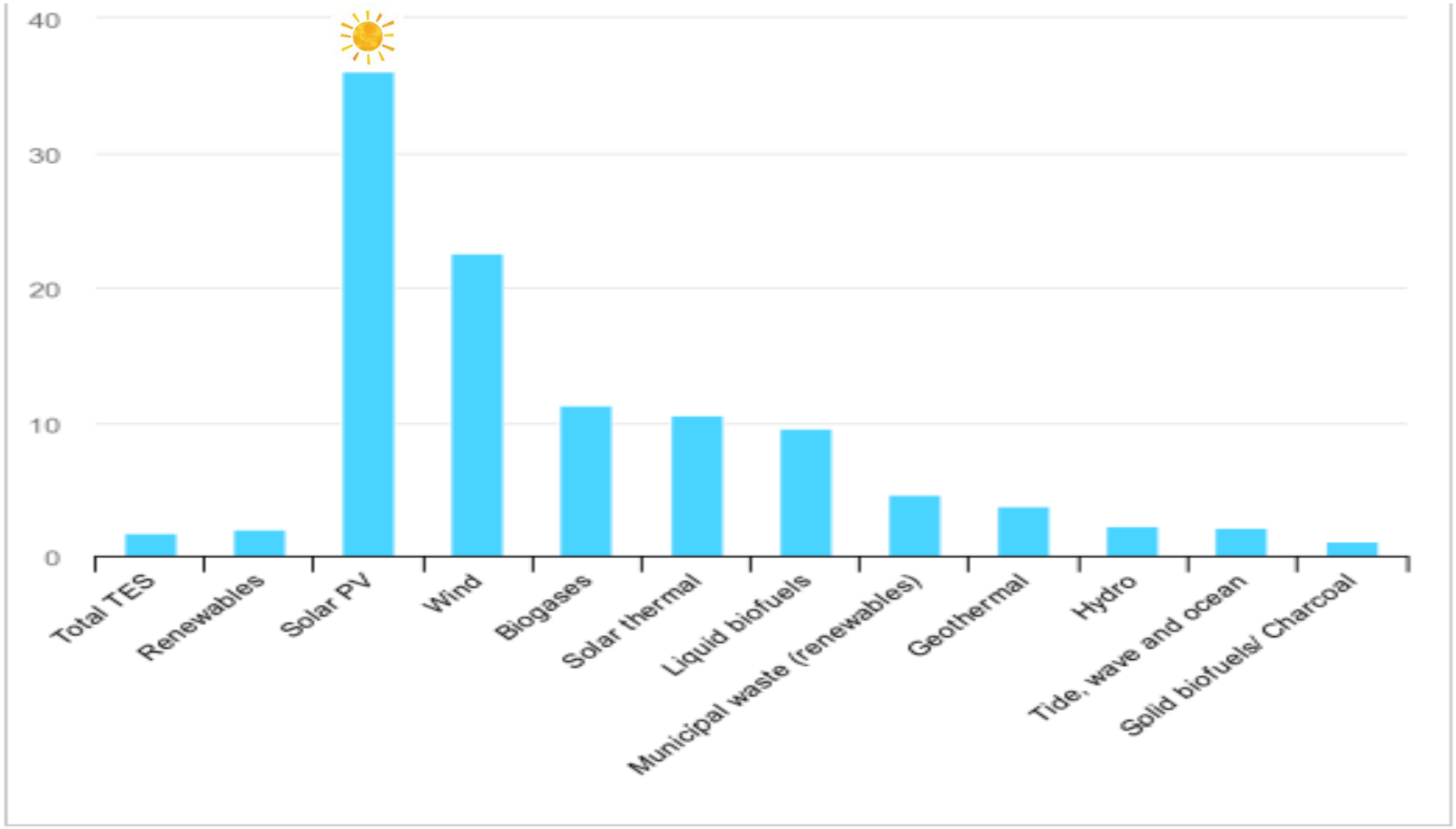
Climate Change policies

- All countries want to see global emissions fall, but incentive is to free-ride off the efforts of others
  - Parallel to (global) under-investment in R&D in face of international spillovers
- Need green innovation as carbon tax + regulation insufficient (even if politically feasible)
- Can policy direct this kind of technical change? e.g.
  - Acemoglu et al (2012, 2016): clean energy
  - Aghion et al (2016): Electric cars & fuel price
  - Acemoglu et al (2022): Shale Gas
- Can industrial policy benefit a country as well as world?
  - Burgess and Van Reenen (2022): "**Solar"**

Some Good news: The rapidly falling cost of solar energy



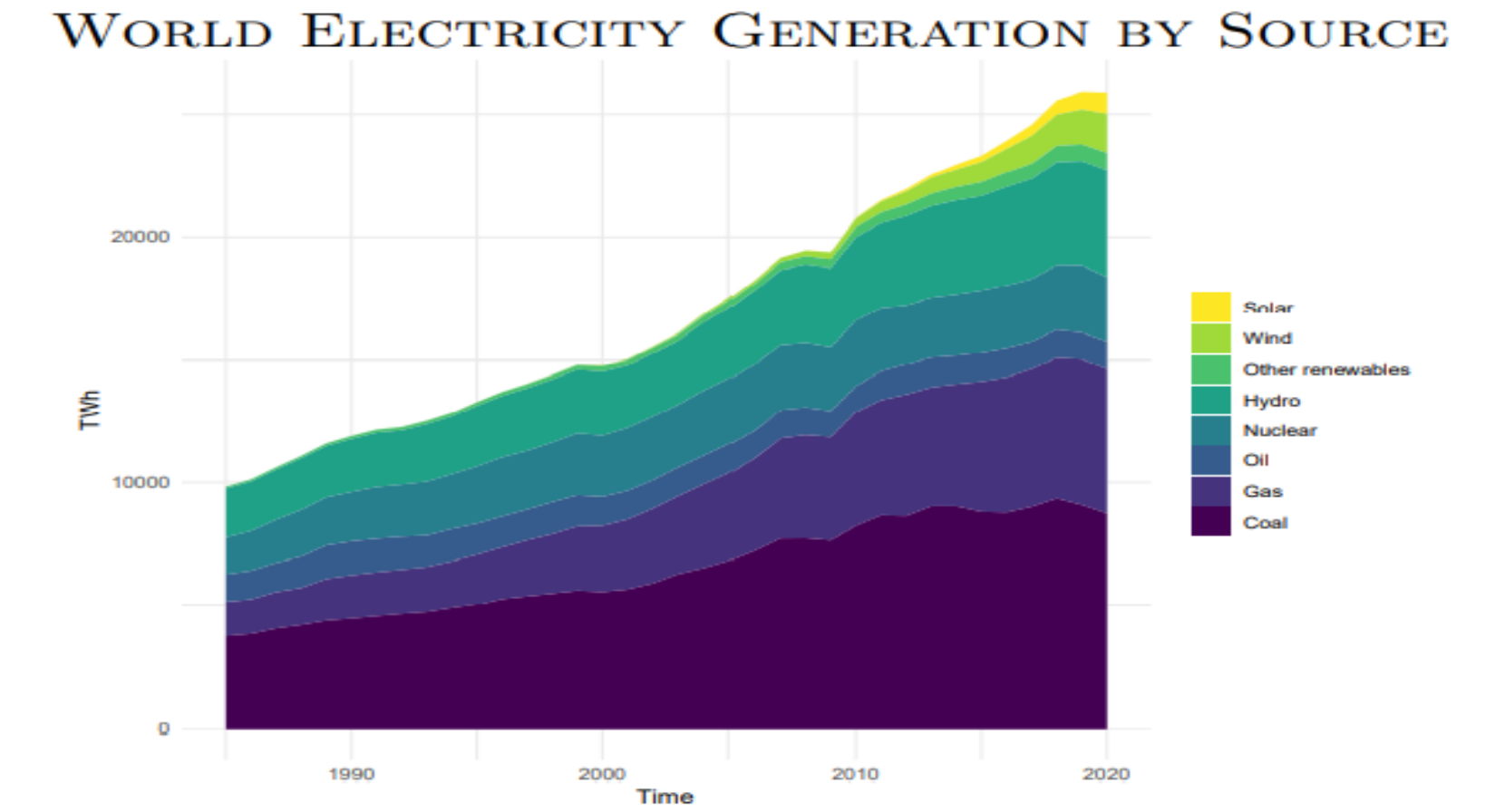
Solar is a large share of installations since 1990….



Notes: IEA, 1990-2019. **TES** stands for **Total Energy Supply**

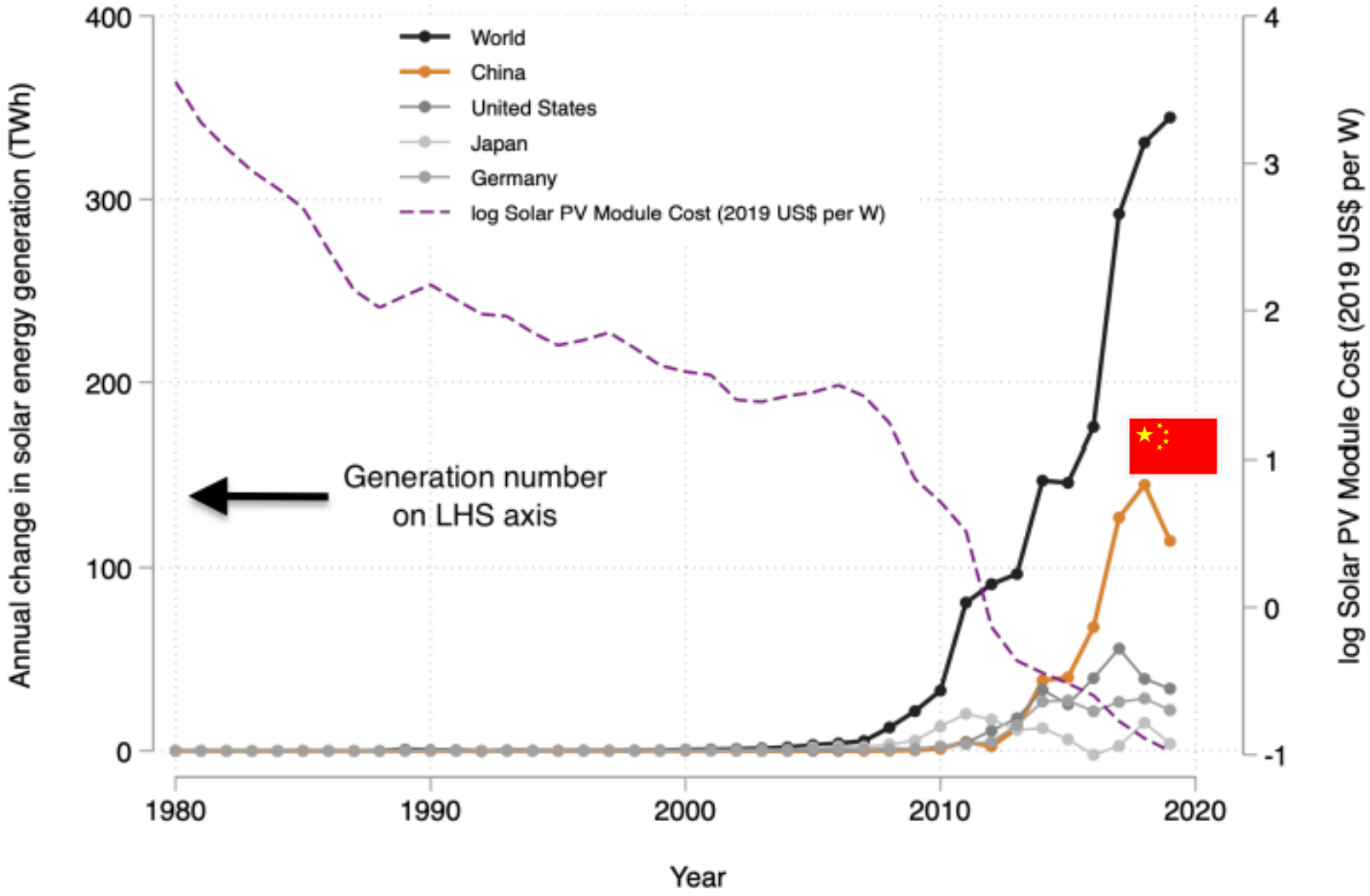
Note: Average Annual Growth Rates of World Renewables Supply

….But still a small share of world electricity capacity

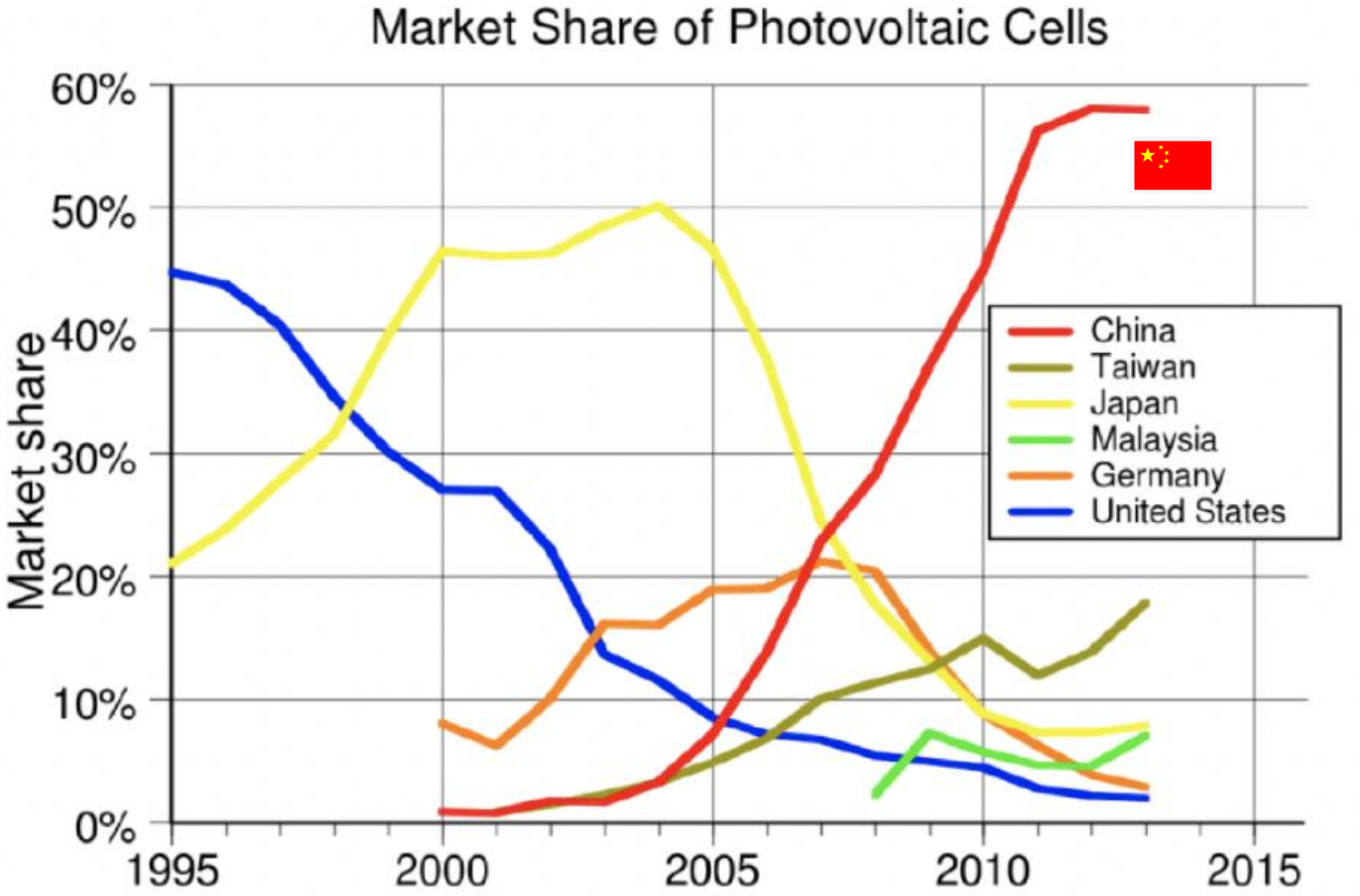


Source: Our World in Data based on BP Statistical Review of World Energy & Ember (2022)

Global expansion of solar generation is led by China

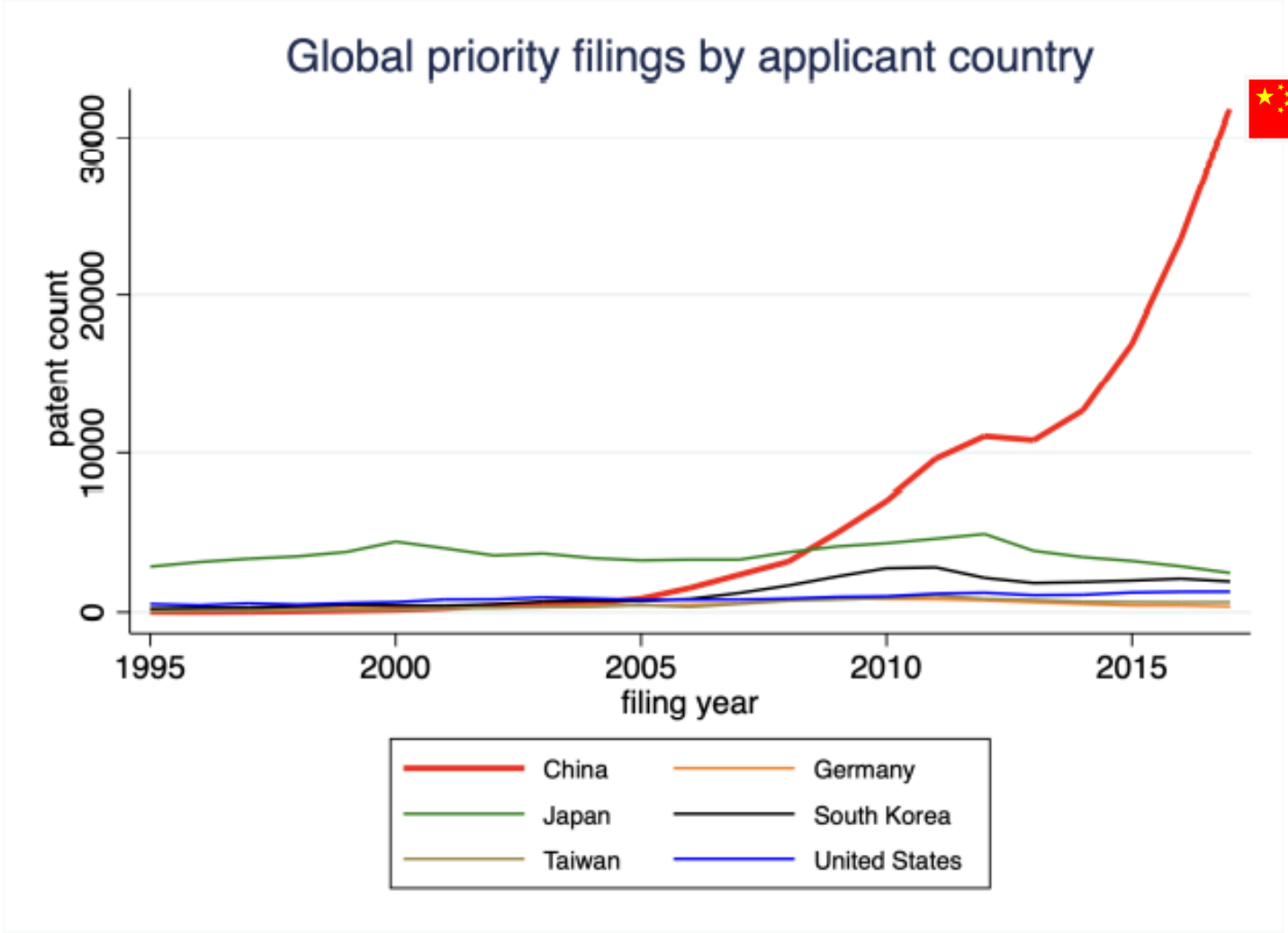


Rapid Growth in importance of China in Solar Production



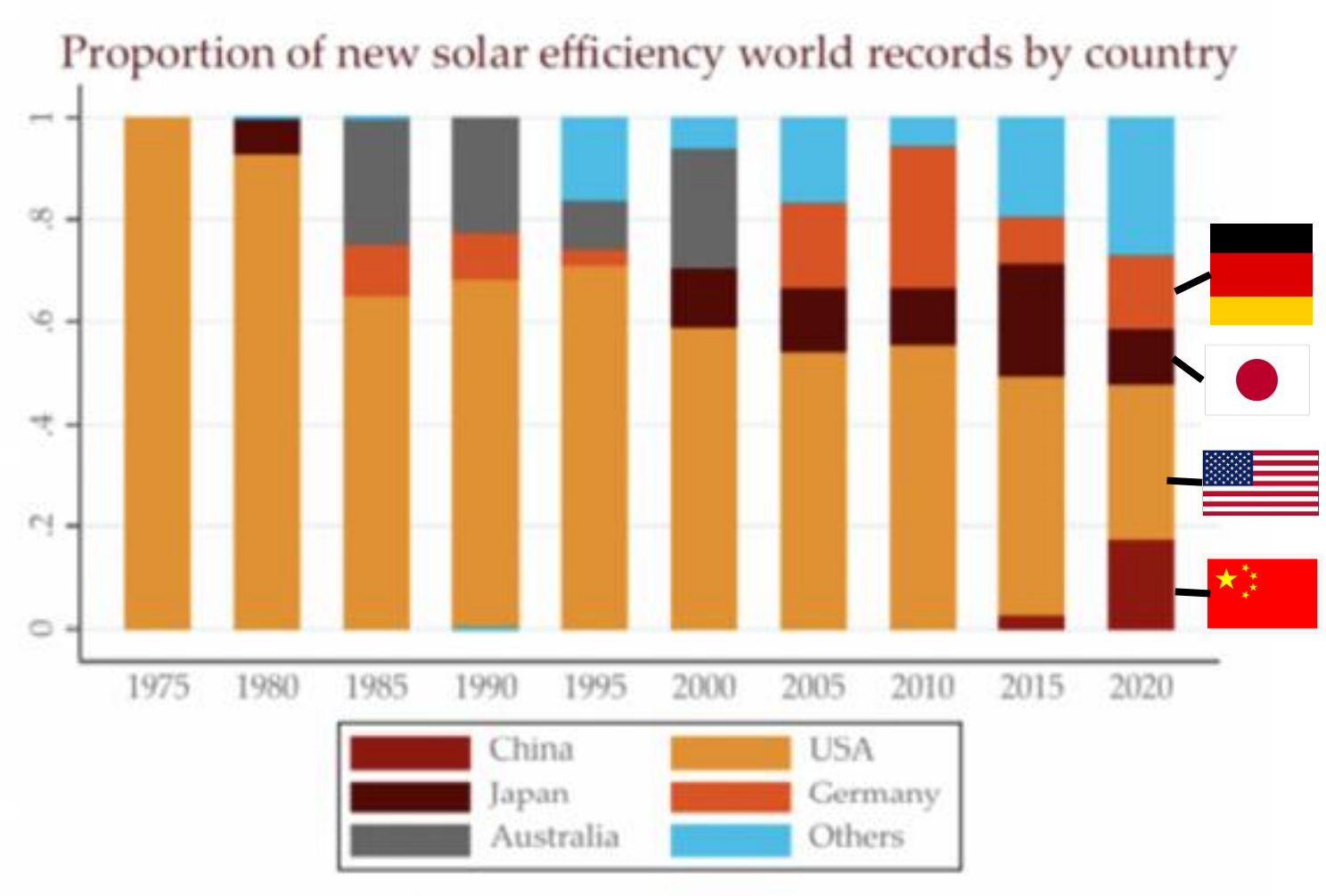
Source: World's largest solar PV producers: China, Taiwan, US, Japan, Germany, & Malaysia (1995-2013). Data sources are IEA-PVPS and Earth Policy Institute

China is not just imitating: Also producing innovations

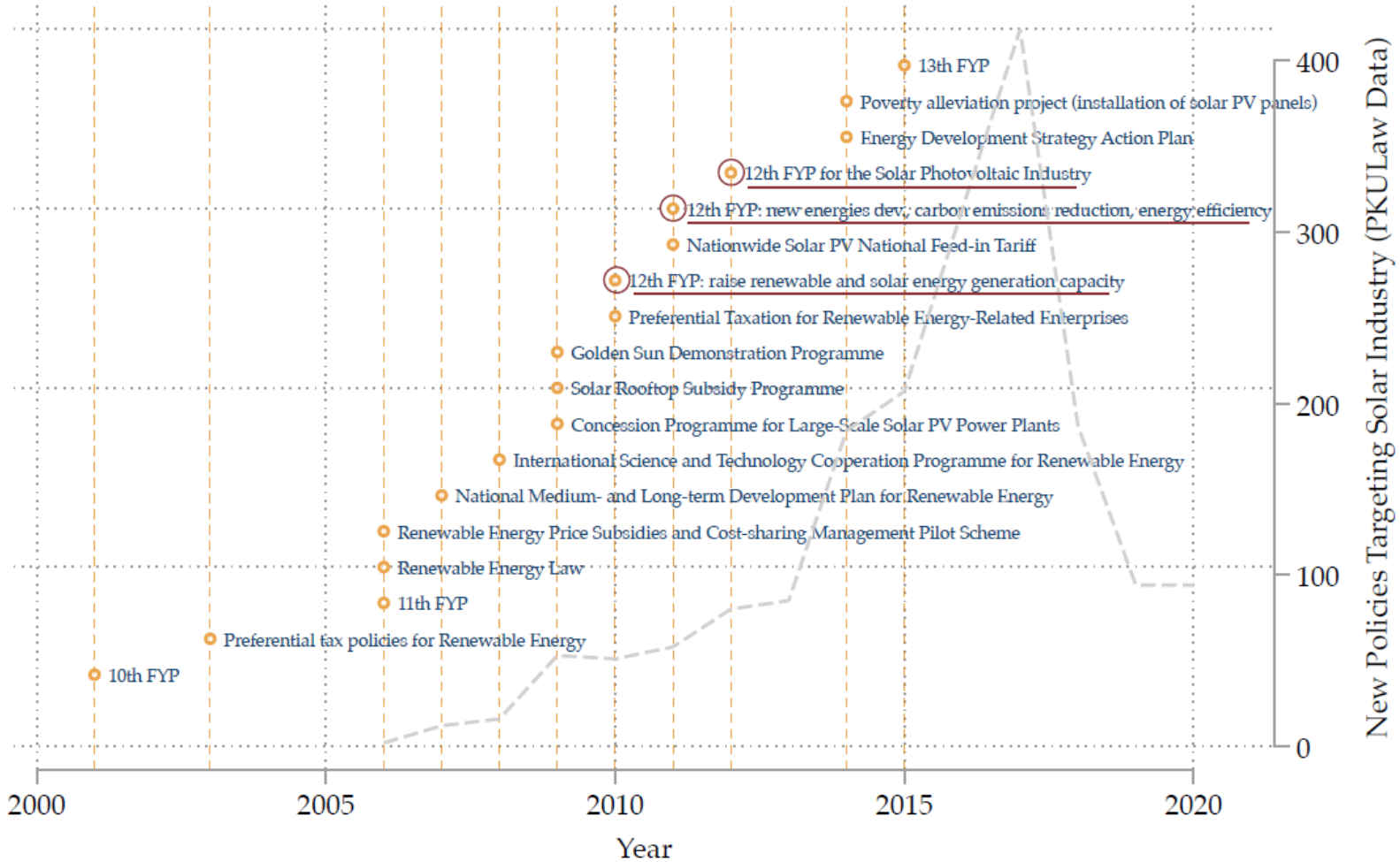


Source: PATSTAT database

China expanding presence at the Solar technology frontier

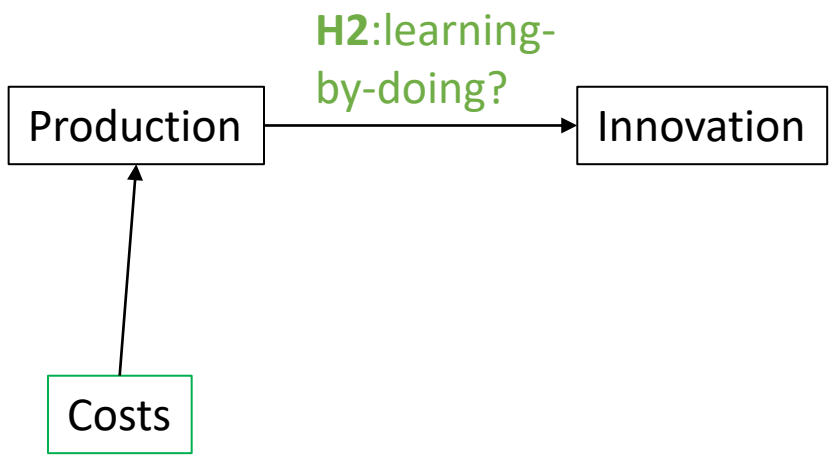


Big policy efforts towards solar in China



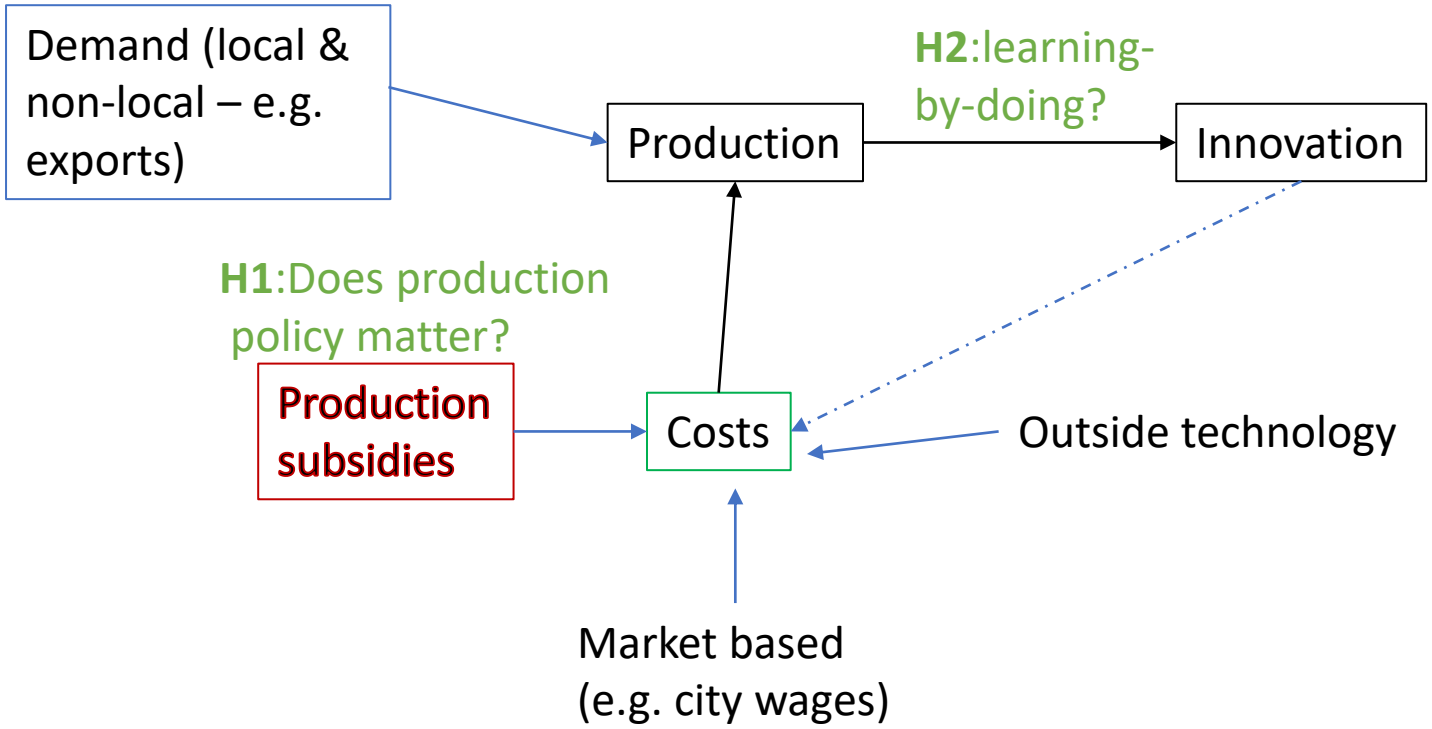
Note: Policy support time series in gray comes from PKULaw dataset. Highlighted main policies are from (Shubbak, 2019)

Causal Graph of Chinese Solar Industry and policy



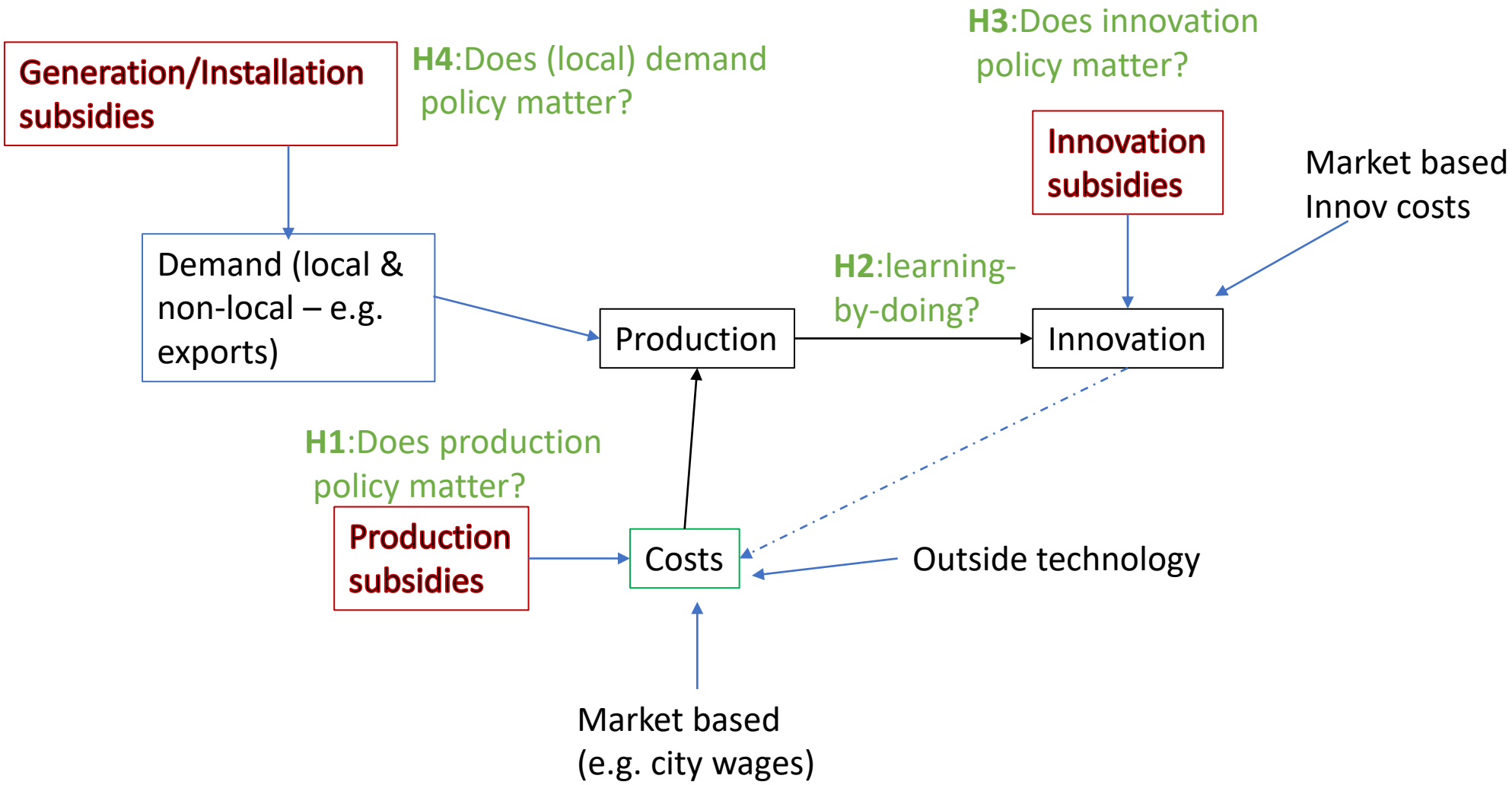
Note: This could be at city or firm level (depending on spillover assumptions); but could also be estimated at plant, province, country or even global level

Causal Graph of Chinese Solar Industry and policy



Note: This could be at city or firm level (depending on spillover assumptions); but could also be estimated at plant, province, country or even global level

Causal Graph of Chinese Solar Industry and policy



Note: This could be at city or firm level (depending on spillover assumptions); but could also be estimated at plant, province, country or even global level

Data

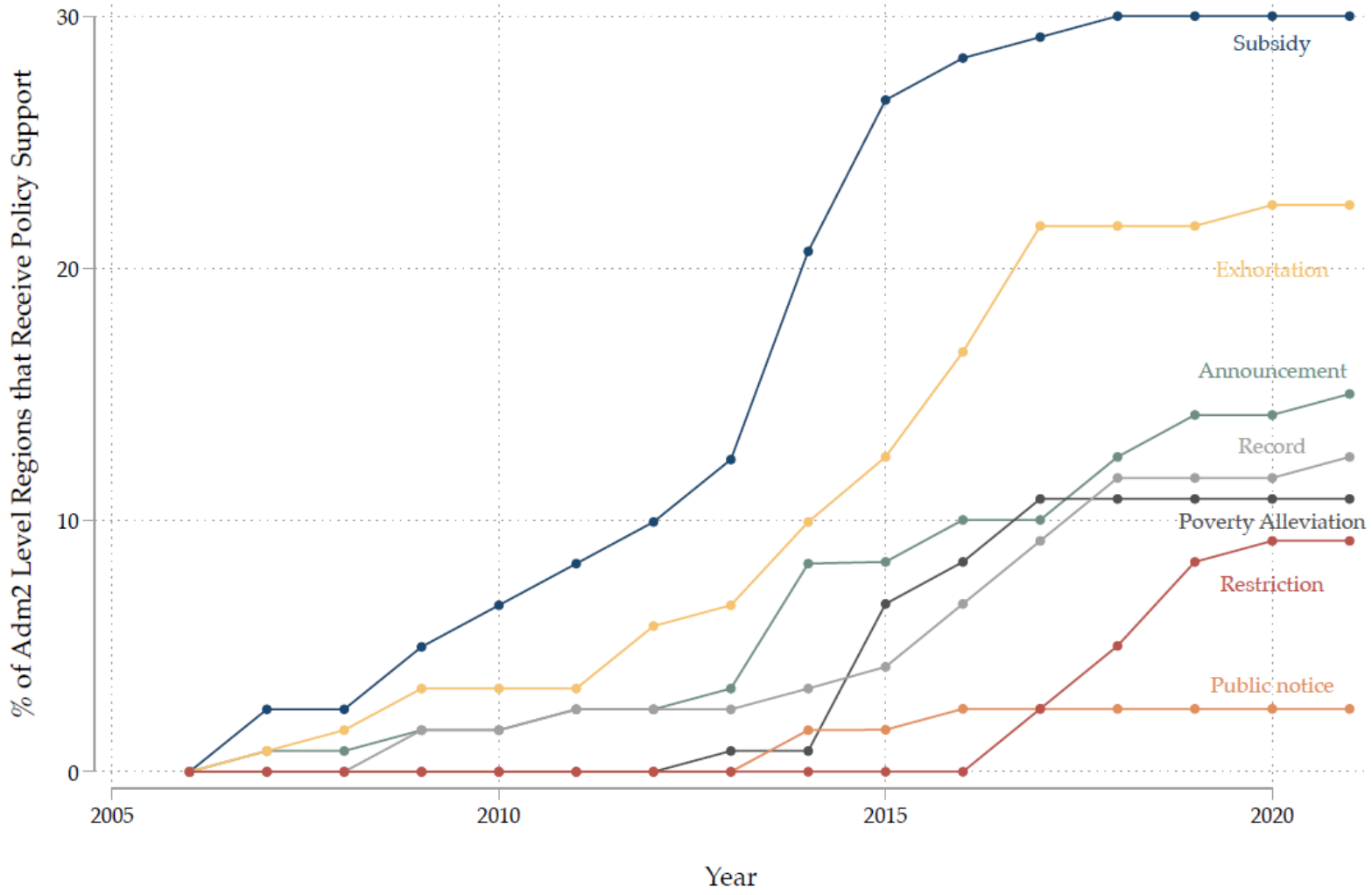
- Firm level **capacity, production, input** data from ENF & ASIE from 2004 on all solar firms (aggregated to city-year level); exports from Customs data

- **Solar patent data**: State Intellectual Property Office of China (SIPO) 2000 to 2019. Aggregated to city level

- **Policy data:** PKUlaw, solar related policies from 2004 to 2021 at city, province and national levels

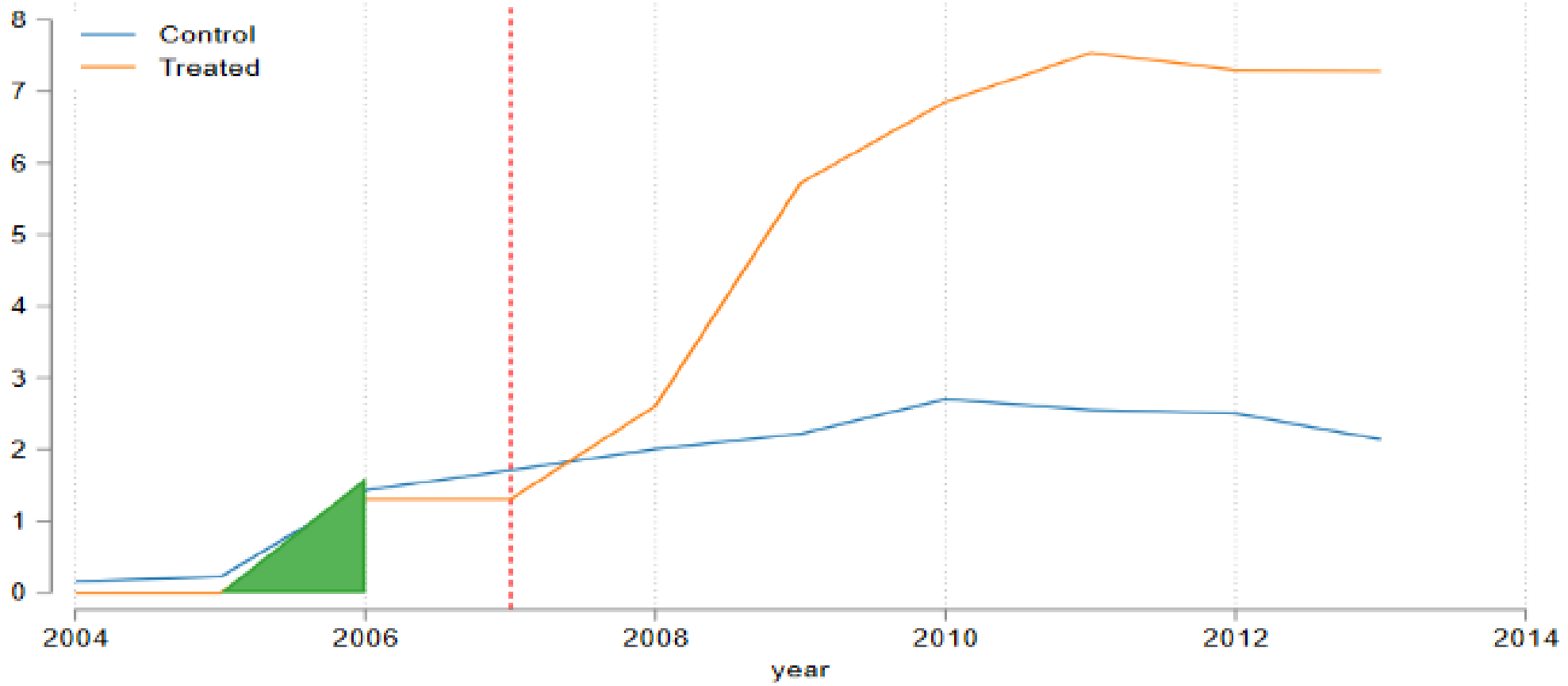
- **City level economic data**: population and GDP from the statistics yearbooks.

Fraction of Chinese cities with Solar subsidy policies, 2006-2021



Note: *Source: PKULaw laws & regulations dataset; out of 120 adm2 regions with any Solar firms*

Increase in Total Solar Cell capacity after a city introduces a solar policy (2007 cohort, Time period: 2004-2013); SDID estimates



Notes: Estimates of solar policies at city level using Synthetic Diff-In-Diffs (Arkhangelsky, Athey, Hirshberg, Imbens and Wager: SDID/AAHIW, 2021). Dependent variable is log(Solar Cell Capacity). No controls. 2007 treatment only. Green triangle shows weighting of pre-policy periods.

City-level Solar Policies appear to raise solar capacity

		All subsidies		
Dependent variable:	**Controls?**	**ATT**		
Cell Capacity				
	No	1.75** (0.011)		
	Yes	2.01*** (0.004)		
Panel Capacity				
	No	1.58*** (0.010)		
	Yes	1.67*** (0.006)		

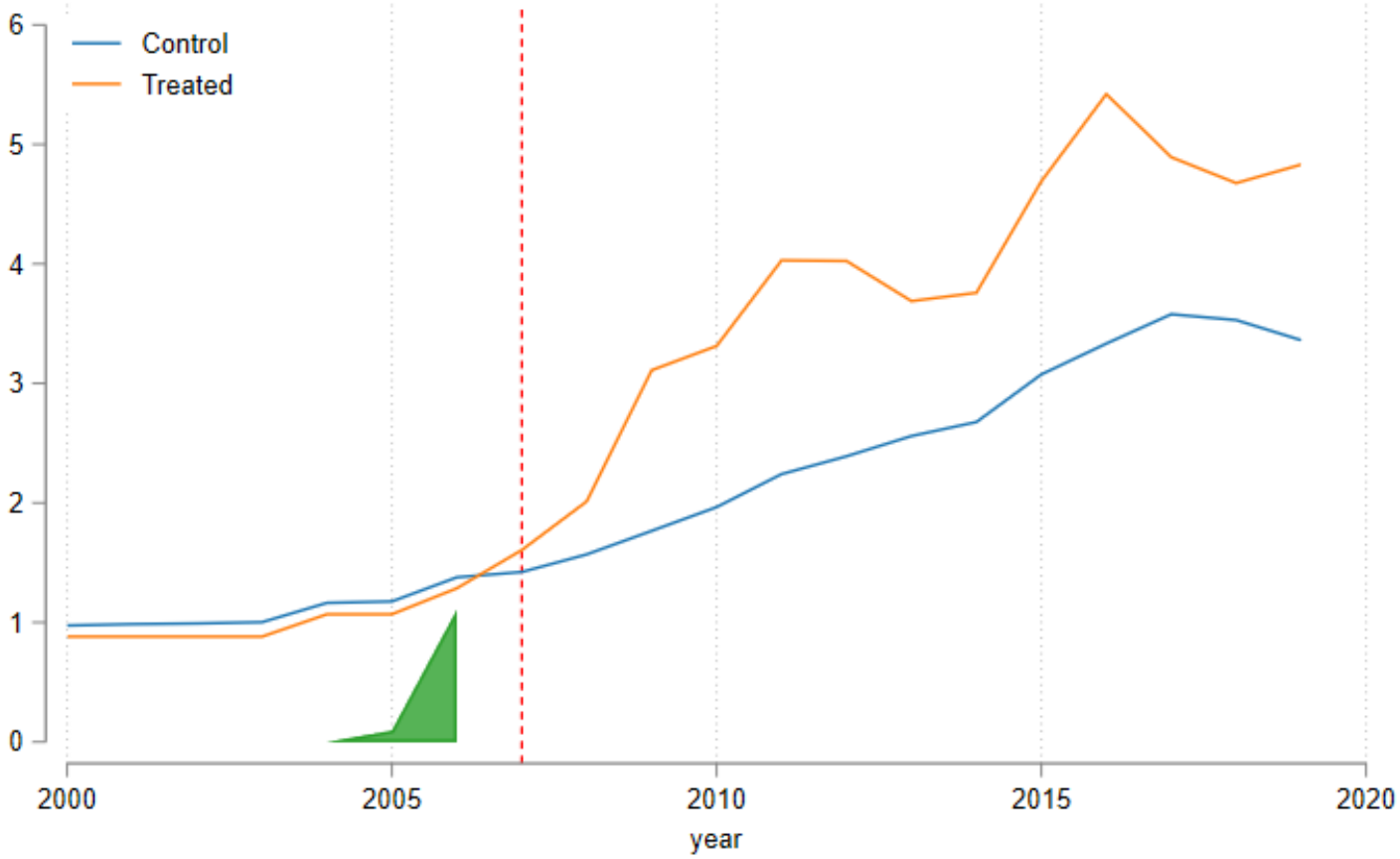
Notes: Estimates of solar policies at city level using SDID (AAHIW, 2021). Dependent variable is log(Solar Cell Capacity). Controls are log(GDP) and log(population). These are missing for a few cities; p-values in parenthesis under the coefficient. * p<0.1, ** p<0.05, *** p<0.01. Demand subsidies are for generation of power, supply side are for location of solar production. Time Period is 2004-2013

City-level Supply Side Solar Policies appear to raise solar capacity

		All subsidies	Demand subsidies	Supply subsidy
Dependent variable:	**Controls?**	**ATT**	**ATT**	**ATT**
Cell Capacity				
	No	1.75** (0.011)	1.24* (0.077)	1.90** (0.037)
	Yes	2.01*** (0.004)	1.23* (0.080)	2.24** (0.015)
Panel Capacity				
	No	1.58*** (0.010)	0.60 (0.144)	1.88** (0.012)
	Yes	1.67*** (0.006)	0.60 (0.144)	2.00*** (0.006)

Notes: Estimates of solar policies at city level using SDID (AAHIW, 2021). Dependent variable is log(Solar Cell Capacity). Controls are log(GDP) and log(population). These are missing for a few cities; p-values in parenthesis under the coefficient. * p<0.1, ** p<0.05, *** p<0.01. Demand subsidies are for generation of power, supply side are for location of solar production. Time Period is 2004-2013

Increase in Patenting after a city is treated in 2007 (longer lags than than solar output), 2004-2019



Notes: Estimates of solar policies at city level using SDID (AAHIW, 2021). Dependent variable is asinh(Patent Count). No controls. 2007 treatment only

City-level Solar Policies appear to raise solar patenting

		All subsidies			
Smaller sample?	**Controls?**	**ATT**			
No	No	0.43*** (0.001)			
Yes	No	0.42*** (0.000)			
Yes	Yes	0.43*** (0.000)			

Notes: Estimates of solar policies at city level using SDID (AAHIW, 2021). Dependent variable is asinh(number of Solar Firms). Controls are log(GDP) and log(population). These are missing for a few cities so we show the results on larger sample where we do not have these controls as well as the smaller sample where we do have them. p-values in parenthesis under the coefficient. * p<0.1, ** p<0.05, *** p<0.01. Demand subsidies are for generation of power, supply side are for location of solar production.

Innovation policies most effective in raising patenting; then supply subsidy. Demand policies generally insignificant.

		All subsidies	Demand subsidy	Supply subsidy	Innovation subsidy
Smaller sample?	**Controls?**	**ATT**	**ATT**	**ATT**	**ATT**
No	No	0.43*** (0.001)	0.14 (0.168)	0.64*** (0.000)	0.77*** (0.000)
Yes	No	0.42*** (0.000)	0.18 (0.080)	0.58*** (0.000)	0.73*** (0.000)
Yes	Yes	0.43*** (0.000)	0.17* (0.088)	0.61*** (0.001)	0.72*** (0.000)

Notes: Estimates of solar policies at city level using SDID (AAHIW, 2021). Dependent variable is asinh(number of Solar Firms). Controls are log(GDP) and log(population). These are missing for a few cities so we show the results on larger sample where we do not have these controls as well as the smaller sample where we do have them. p-values in parenthesis under the coefficient. * p<0.1, ** p<0.05, *** p<0.01. Demand subsidies are for generation of power, supply side are for location of solar production.

Summary

- Chinese cities introducing solar policies appear to have successfully increased **production and capacity of solar cells & modules** as well as number of solar firms.

- This is driven by **supply side subsidies** (rather than policy-induced greater demand)

- Policies also appear to increase **patenting** activity (with a lag). Strongest effects from innovation policies, but also some effect from supply side policies. Little/zero effect from demand side policies.

Implications

- Solar policies around the world influence innovation incentives (e.g. German feed-in tariffs in 2000s)
- Chinese Industrial policy massively increased supply, lowered prices and subsidized innovation
- If it benefited China as well as world, then helps overcome policy free riding
- Lessons for other clean technologies: Wind, Hydrogen, etc.?

OUTLINE OF TALK

Threats and Opportunities

Productivity

Climate Change

Defense

Health

The Political Challenge

Successful Innovation Policies? R&D Grants

- Direct government grants (can be better targeted better than tax). e.g. Health (Azoulay et al ‘19); Green Energy (Howell, ’17)
  - Well designed public R&D programs **crowd-in** private innovation on average
- Moretti, Steinwender & Van Reenen ‘22 use **defense shocks** across ~30 year period:
  - Industry-country AND French firm level panel data
  - Find 10% more public R&D stimulates ~5% more private sector R&D in long-run
- But **nature** of R&D procurement also matters
  - Howell et al ‘22 study USAF R&D “Open” procurement reform: by decentralizing increased innovation, diffusion & entry

OUTLINE OF TALK

Threats and Opportunities

Productivity

Climate Change

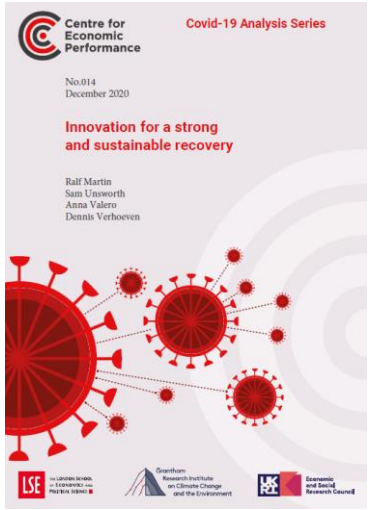
Defense

Health

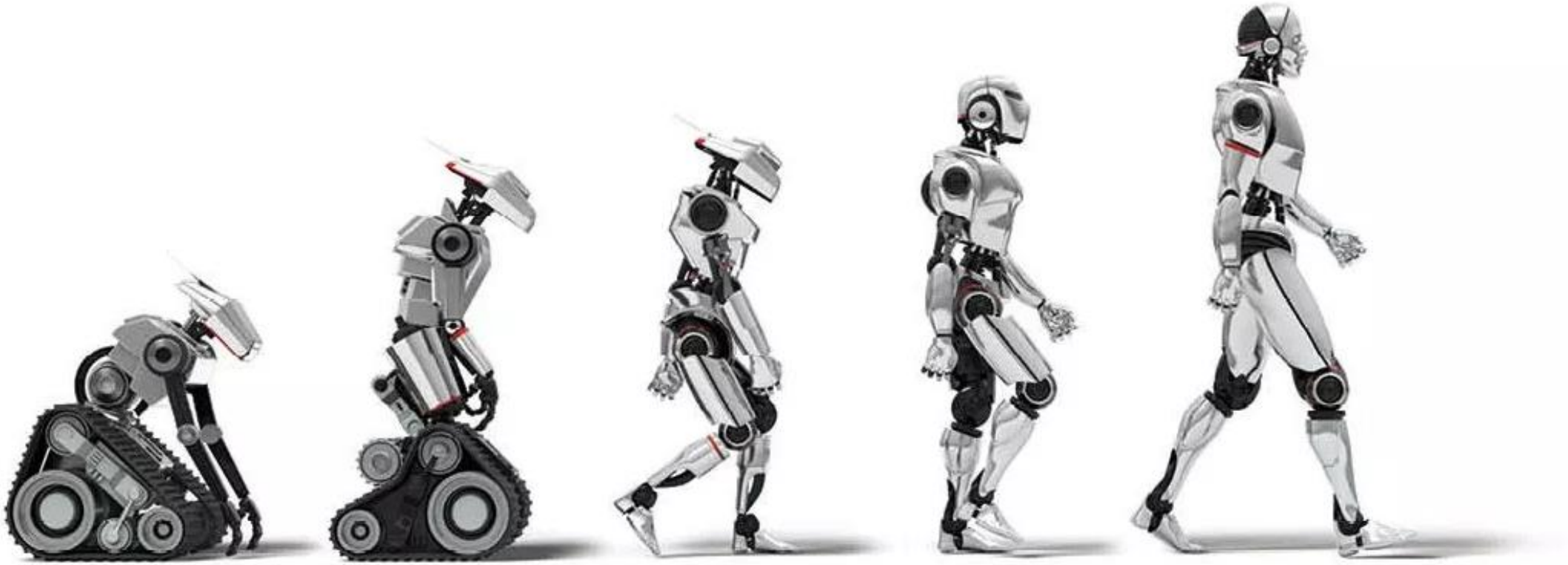
The Political Challenge

A New Marshall for Growth

- Big threats, but also opportunities for creative policies, especially around innovation
- We know much about what can be achieved evidence: e.g.:
  - *Structural* (**competition**, trade, skills, tax & subsidies; infrastructure, etc.)
  - *Direct* (e.g. management information and training)
- Country-specific plans based on best evidence:
  - Toolkits for innovation & management policy
- Bind together in a **mission**:
  - Climate Change; Defense; Healthcare



THANKS!



Some Further Reading (and viewing)

"Innovation Policies to Boost Productivity" (2020) Hamilton Policy Proposal 2020-13 https://www.hamiltonproject.org/assets/files/JVR_PP_LO_6.15_FINAL.pdf webinar

"A Toolkit of Policies to promote Innovation" (Nick Bloom, Heidi Williams and John Van Reenen), *Journal of Economic Perspectives (2019)* 33(3) 163–184 http://cep.lse.ac.uk/pubs/download/dp1634.pdf

"Why Do We Undervalue Competent Management" (Raffaella Sadun, Nick Bloom and John Van Reenen) *Harvard Business Review* (2017), September-October

"Measuring and Explaining Management practices across firms and nations" (Nick Bloom and John Van Reenen) *Quarterly Journal of Economics* (2007) 122(4), 1351–1408.

"Who Becomes an Inventor in America? The Importance of Exposure to Innovation" (Alex Bell, Raj Chetty, Xavier Jaravel, Neviana Petkova and John Van Reenen), http://cep.lse.ac.uk/pubs/download/dp1519.pdf Data *Quarterly Journal of Economics* (2019)134(2) 647–713, New York Times Vox Atlantic Fortune Conversation VoxUS Economist VC Centrepiece INET

"OPENing up Military Innovation: An Evaluation of Reforms to the U.S. Air Force SBIR Program" (Sabrina T. Howell, Jason Rathje, John Van Reenen and Jun Wong), Vox 2021 https://poid.lse.ac.uk/textonly/publications/downloads/poidwp004.pdf

"The Intellectual Spoils of War: Defense R&D, Productivity and Spillovers" (Enrico Moretti, Claudia Steinwender and John Van Reenen) http://cep.lse.ac.uk/pubs/download/dp1662.pdf Vox

Further reading

- "The World Management Survey at 18" (Scur, Sadun, Van Reenen, Lemos & Bloom, 2021), *Oxford Review of Economic Policy* https://poid.lse.ac.uk/textonly/publications/downloads/poidwp002.pdf

- World Management Survey http://worldmanagementsurvey.org/

- "Increasing Difference Between Firms" *Changing Market Structures and Implications for Monetary Policy*, Jackson Hole Symposium (Van Reenen, 2018) 19-65 http://cep.lse.ac.uk/pubs/download/dp1576.pdf NYT NPR

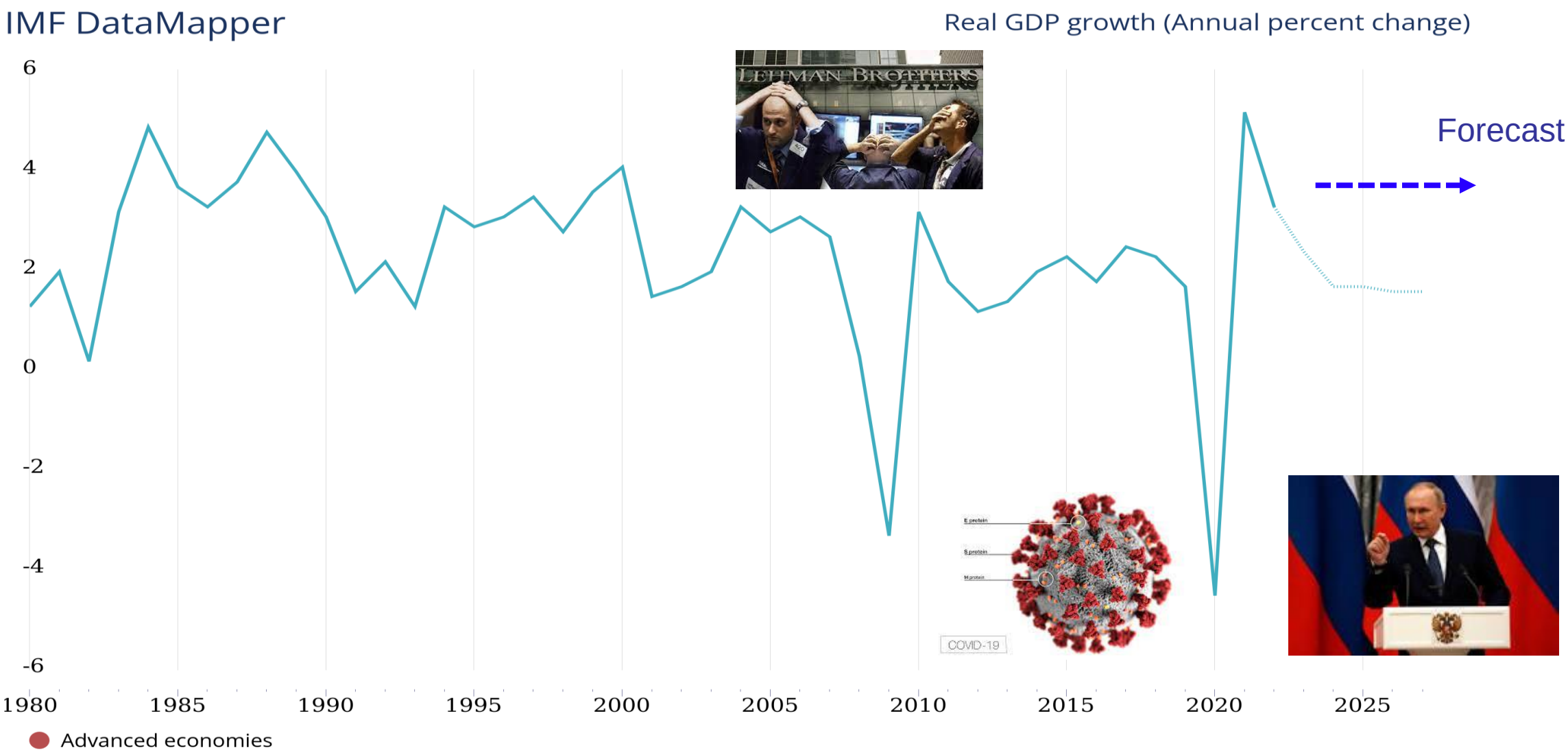
- LSE Growth Commission Final Report (Aghion et al, 2013)

http://www.lse.ac.uk/researchAndExpertise/units/growthCommission/documents/pdf/GCReportSummary.pdf

- "Management as a Technology" (Bloom, Sadun and Van Reenen, 2017): http://cep.lse.ac.uk/pubs/download/dp1433.pdf

- "Do Fiscal Incentives increase innovation? An RD Design for R&D" (Antoine Dechezlepretre, Elias Einio, Ralf Martin, Kieu-Trang Nguyen and John Van Reenen), CEP Discussion Paper 1413 Vox, http://cep.lse.ac.uk/pubs/download/dp1413.pdf

The Big Hit: GDP growth in Advanced Economies, 1980-2022

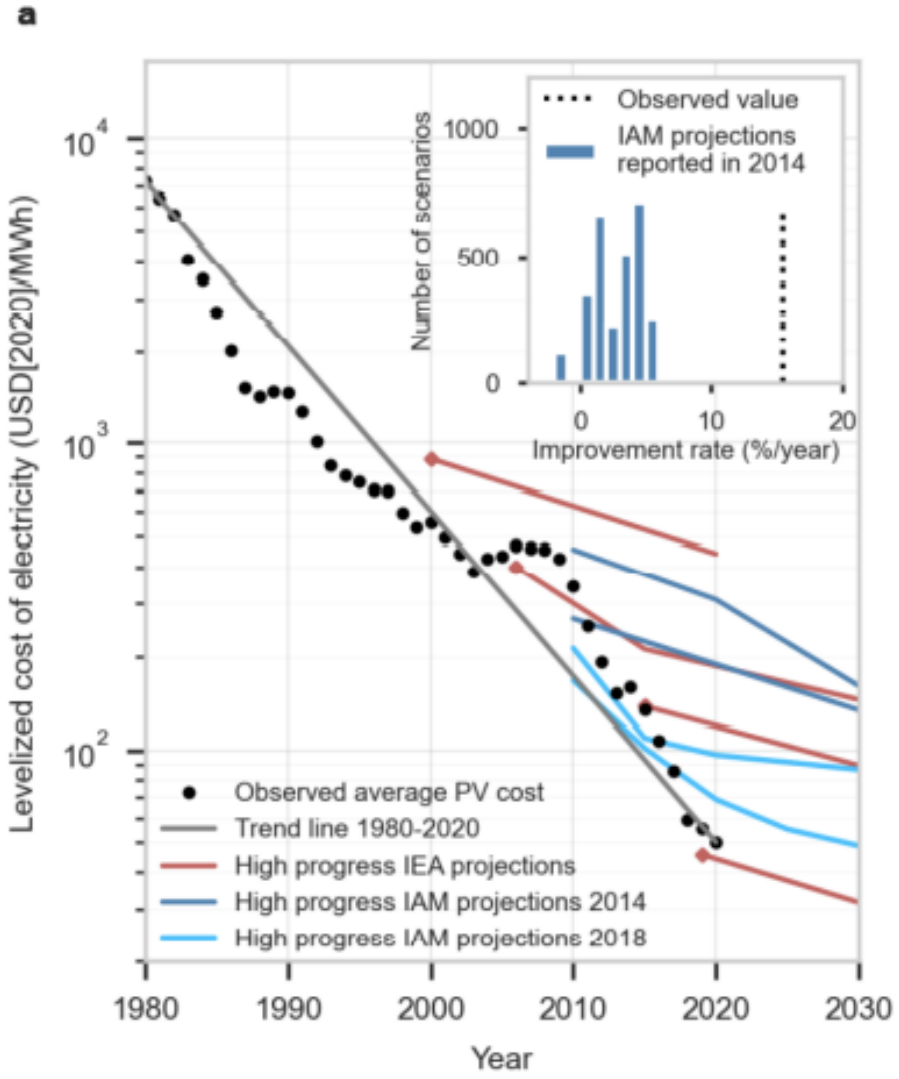


Example of Innovation Policy: R&D tax credits

- **Do Fiscal incentives increase R&D (Hall, 2022)?**
  - Cross country (e.g. Bloom, Griffith & Van Reenen, 2002)
  - Cross state (e.g. Wilson, 2009)
  - Cross firm (e.g. Hall, 1992; Rao, 2016)
  - Elasticity of R&D with respect to user cost >1 (see Blandinieres et al, 2020 meta-study)

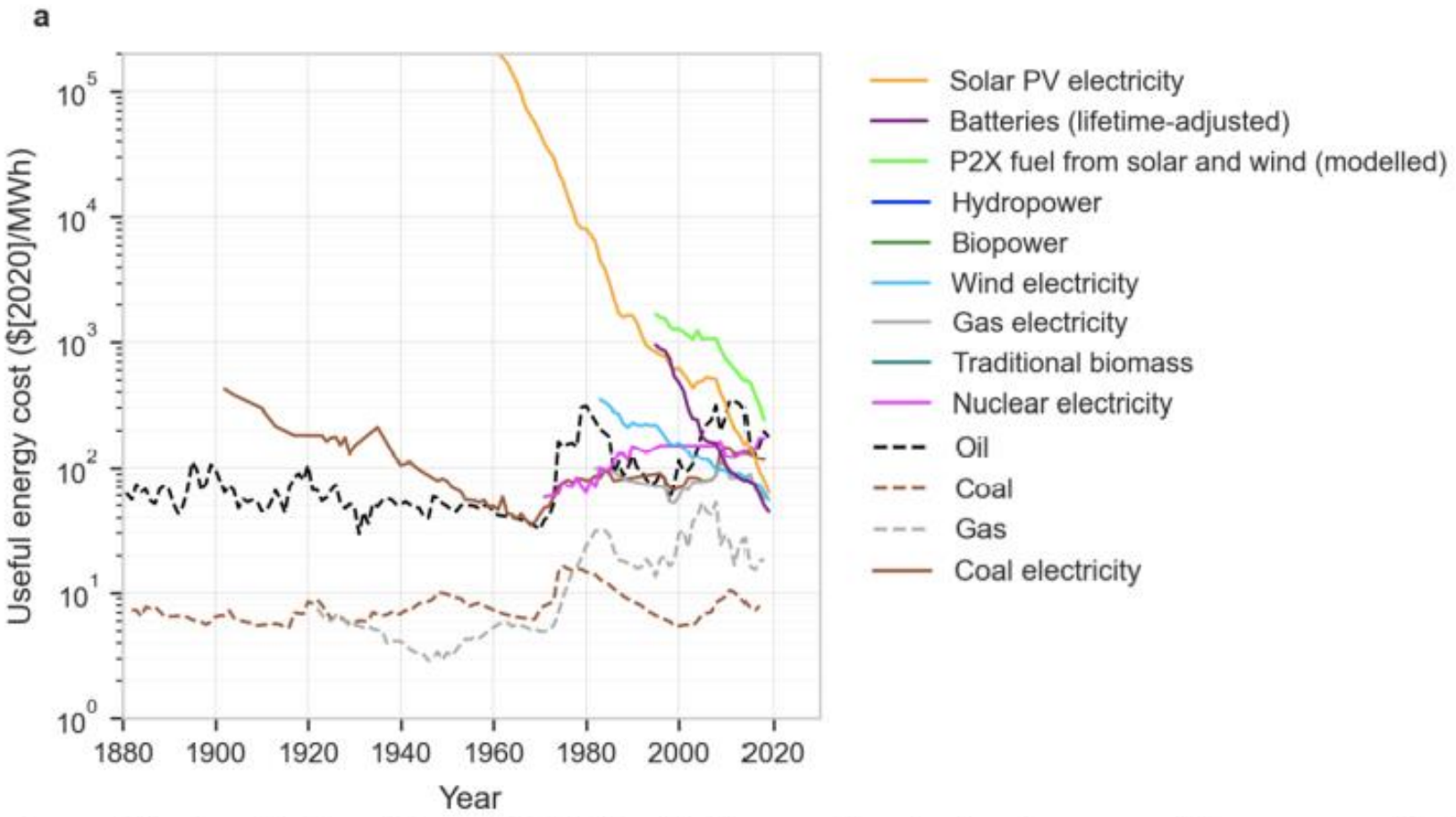
- **Do Fiscal incentives increase *Innovation?***
  - Important because of re-labelling concern (Chen et al, 2021)
  - See also Akcigit et al (2022) and Stantcheva (2022) on general taxation
  - Dechezlepretre et al (2022) using Regression Discontinuity Design. Change in SME R&D thresholds in UK

Falls in solar costs have been much faster than forecast, 1980-2030



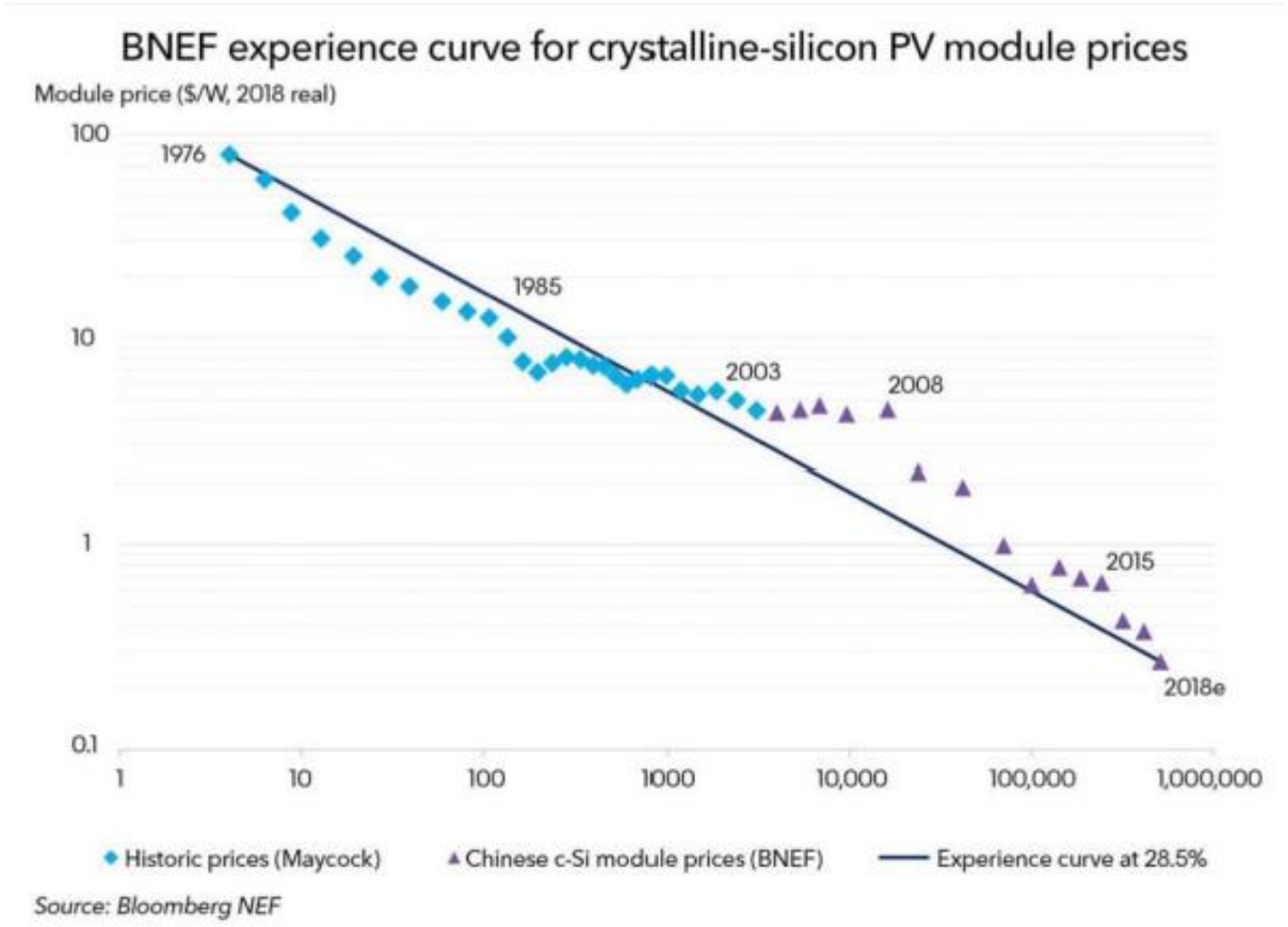
Source: Way et al (2021)

Huge Falls in cost of solar relative to other conventional energy sources (1880-2020)

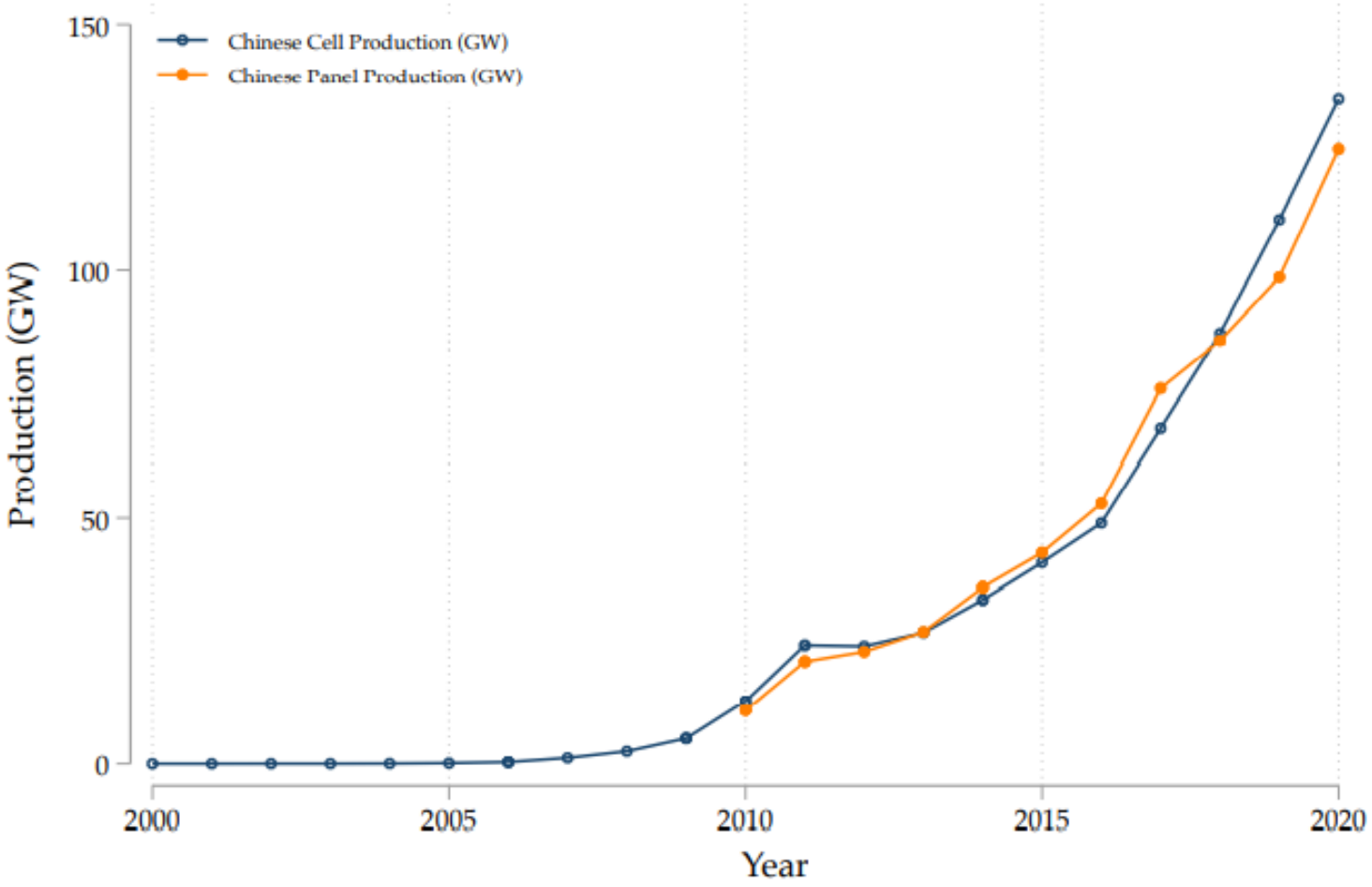


Source: Way, Ives, Mealy and Farmer (2021) "Empirically grounded technology forecasts and the energy transition"

“Experience Curve”: 28.5% reduction in cost per Watt for every doubling of cumulative capacity, 1976-2018

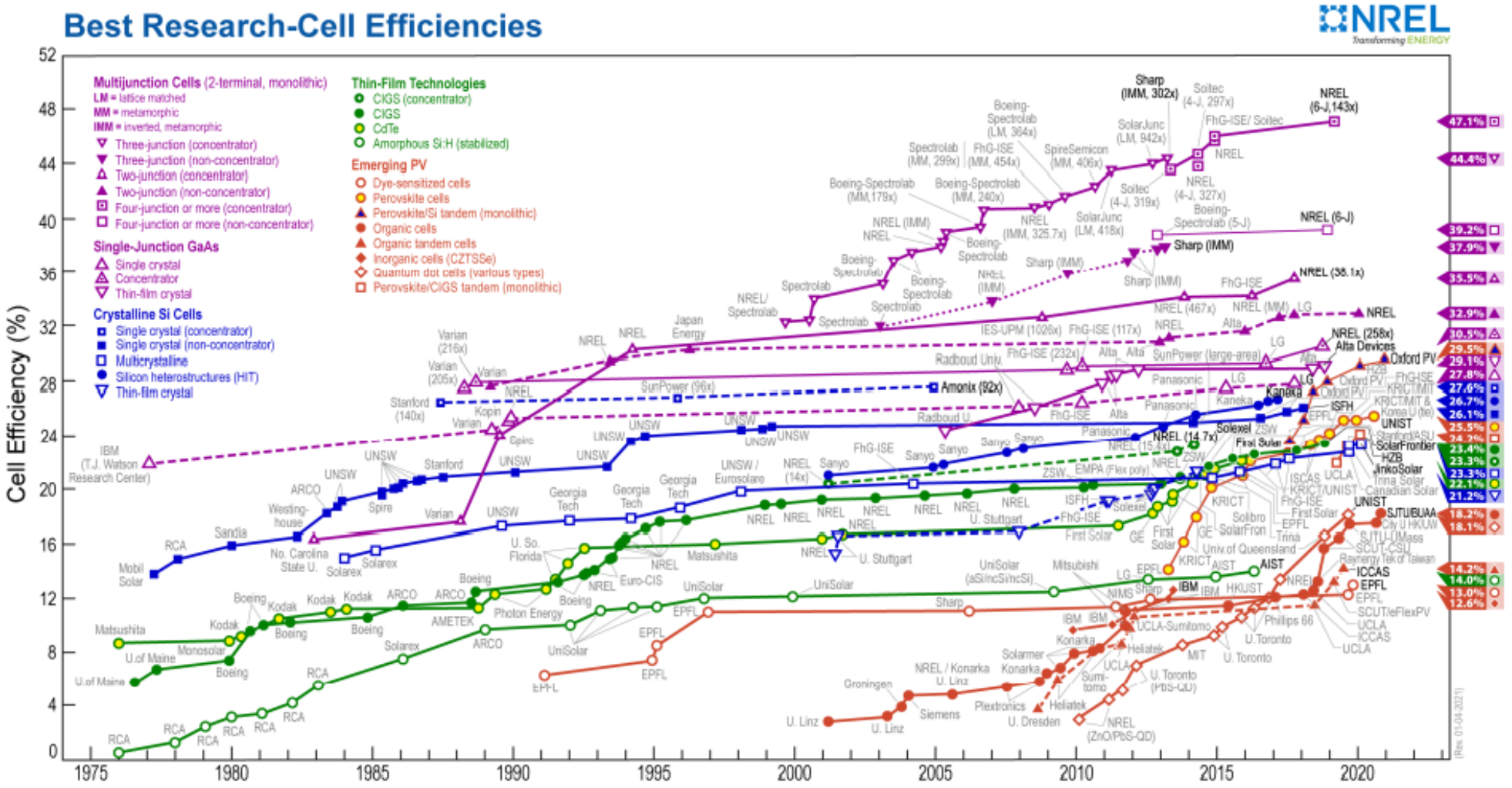


Growth of solar panels & cells production in China

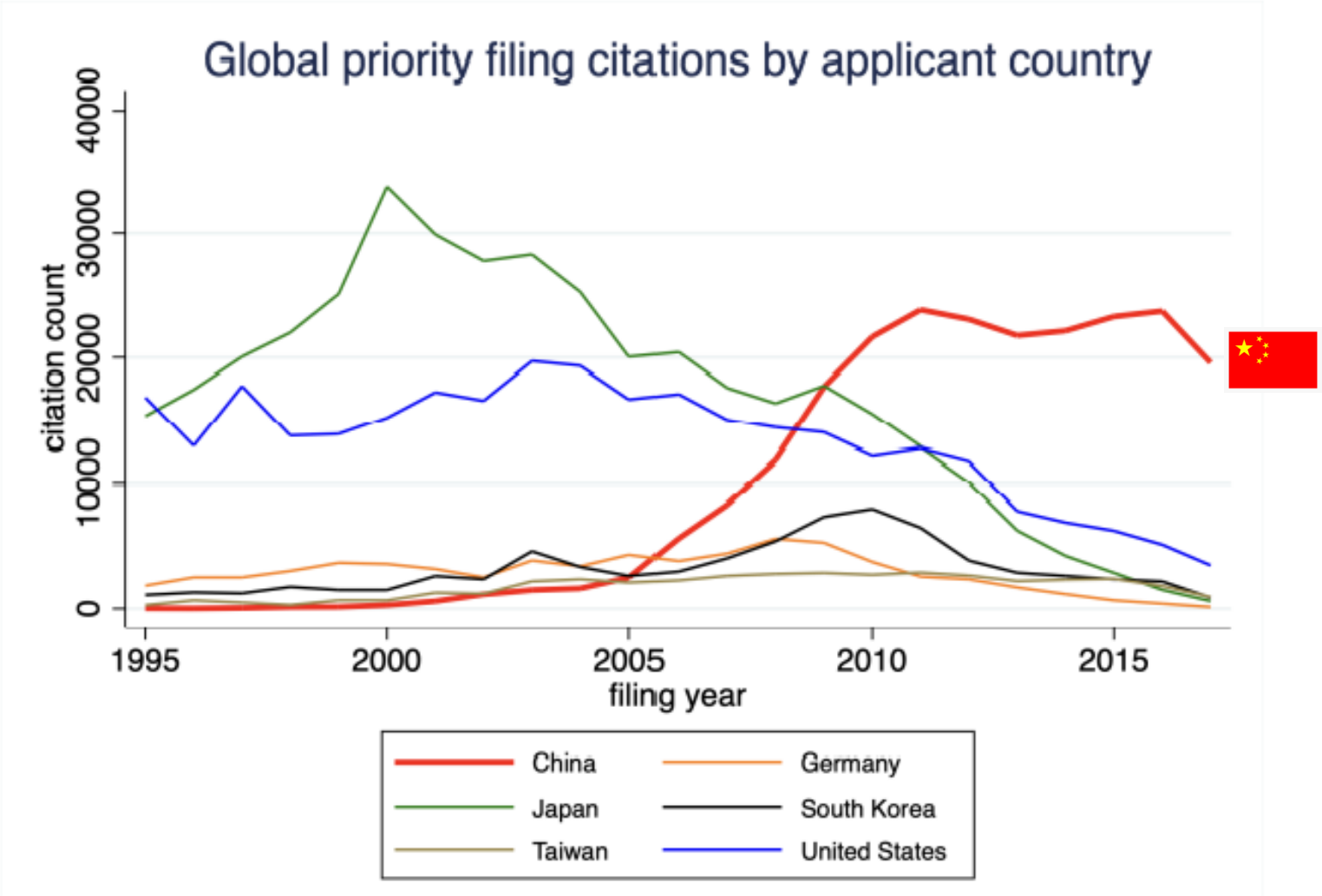


Source: 2020-2021 Annual Report on China's Photovoltaic Industry, based on surveys from China's Solar industry Association

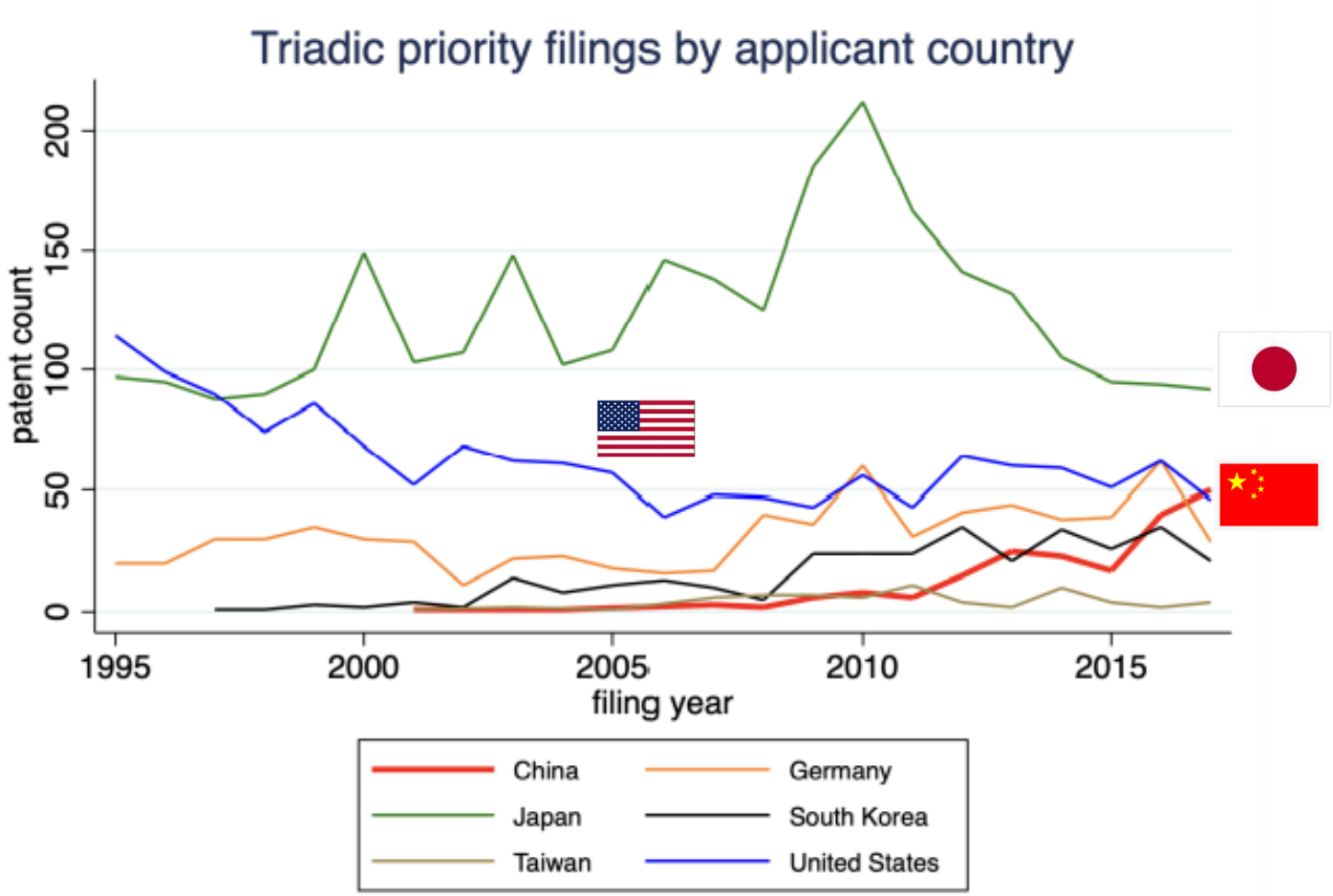
Measuring the Solar technology frontier



Still growth, but China's rise less dramatic weighting by future citations

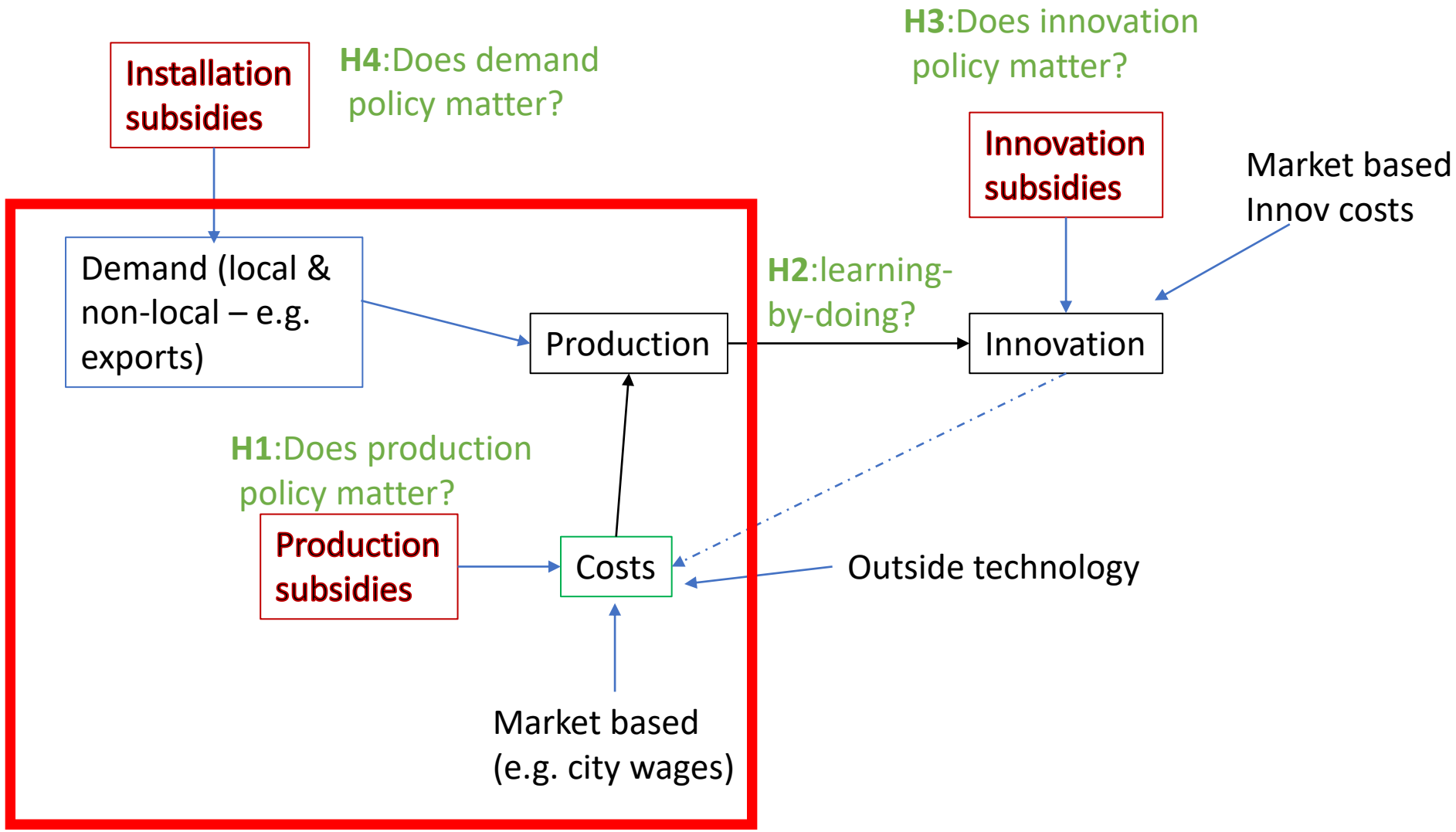


Still growth, but China's rise less dramatic using Triadic Patents



Source: PATSTAT; Triadic patents = granted in USPTO, EPO and JPO

Causal Graph of Chinese Solar Industry and policy: Initial Focus



Note: This could be at city or firm level (depending on spillover assumptions); but could also be estimated at plant, province, country or even global level

Classic Staggered Diff-In-Diff Design

- Solar firms get support depending on their city *j* location
- Exploit staggered nature of policy support over year *t* when policy in effect
- Outcomes (broken down by Solar Cells and Solar panels): Capacity, Production, number of firms and patenting

$$Q_{j,t}^{SOLAR} = \beta POLICY_{j,t}^{Q,SOLAR} + \delta_j + \delta_t + u_{j,t}$$

- Much recent work on these designs (e.g. Chaisemartin & D'Haultfoeuille, 2022 survey)
- Focus on Synthetic Diff-In-Diffs (SDID) today. But also compared to Callaway & Sant'Anna (2020); TWFE, etc.

Synthetic Difference-In-Differences (SDID)

- Arkhangelsky, Athey, Hirshberg, Imbens and Wager (AER, 2021, “AAHIW”)
- Traditional DID assigns each untreated group equal weight. But often issues of comparability and violations of parallel pre-trend
- Synthetic Control (Abadie et al, 2010) assigns different weights to untreated groups. Let computer chooses optimal (linear, non-negative) weights to track the pre-treatment trend of the treatment group
- SDID also chooses time weights rather than using all pre-policy periods. This weight choice follows same procedure as synthetic control

SDID components

- Using pre-treatment data to choose $\hat{\omega}^T$, to make the synthetic control groups as parallel as possible before treatment

$$\hat{\omega}_0 + \hat{\omega}^T Y_{co,pre} \approx Y_{\overline{tr},pre}$$

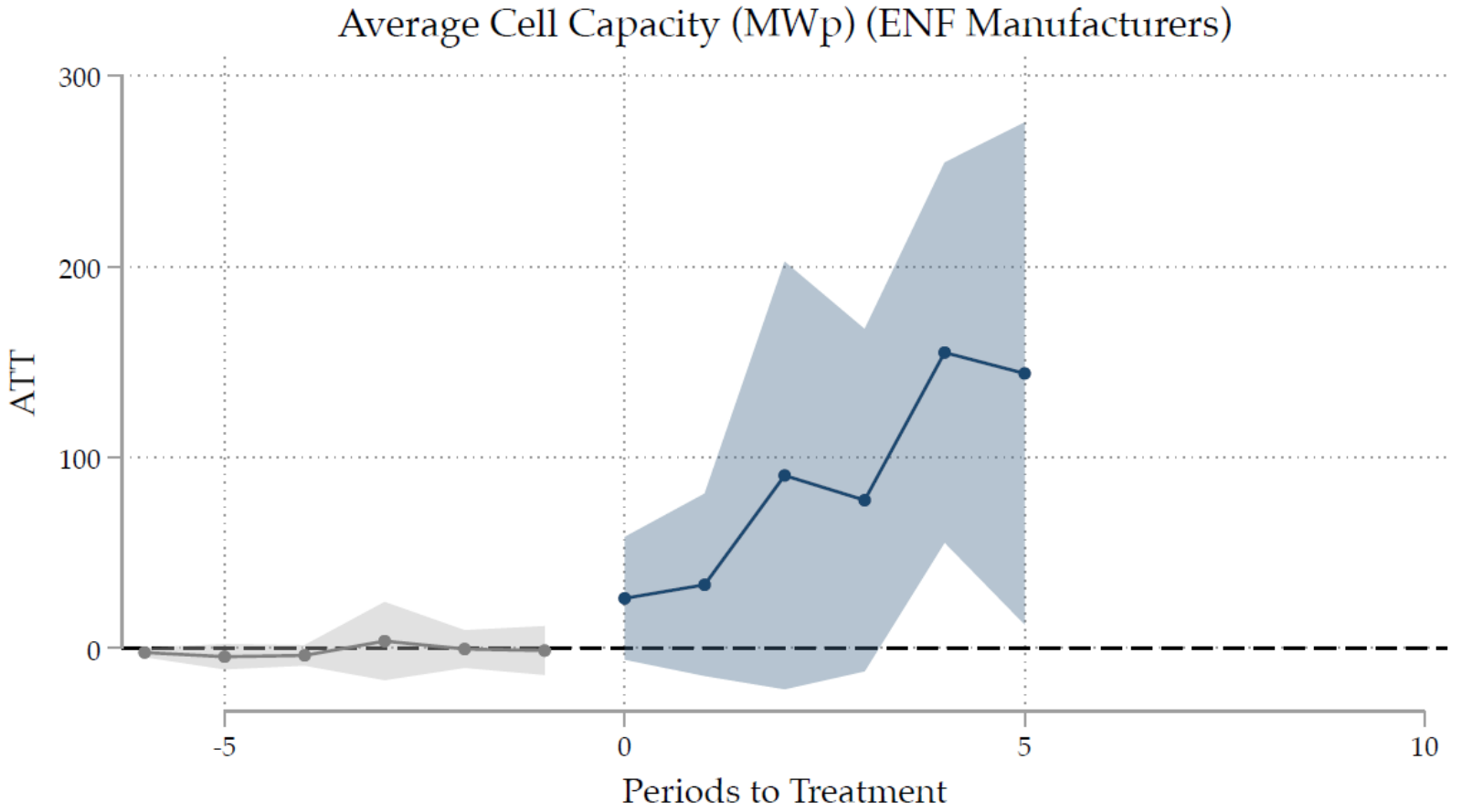
- Estimate time weights $\hat{\lambda}$ using control data. This method weights more on the more recent data before treatment

$$\hat{\lambda}_0 + Y_{co,pre}\,\hat{\lambda} \approx Y_{co,\overline{post}}$$

	Synthetic pre-treatment	Average post-treatment
Synthetic control	$\hat{\omega}^T Y_{co,pre}\hat{\lambda}$	$\hat{\omega}^T Y_{co,\overline{post}}$
Average treated	$Y_{\overline{tr},pre}\,\hat{\lambda}$	$Y_{\overline{tr},\overline{post}}$

$$ATT = \left(Y_{\overline{tr},\overline{post}} - Y_{\overline{tr},pre}\,\hat{\lambda}\right) - \left(\hat{\omega}^T Y_{co,\overline{post}} - \hat{\omega}^T Y_{co,pre}\hat{\lambda}\right)$$

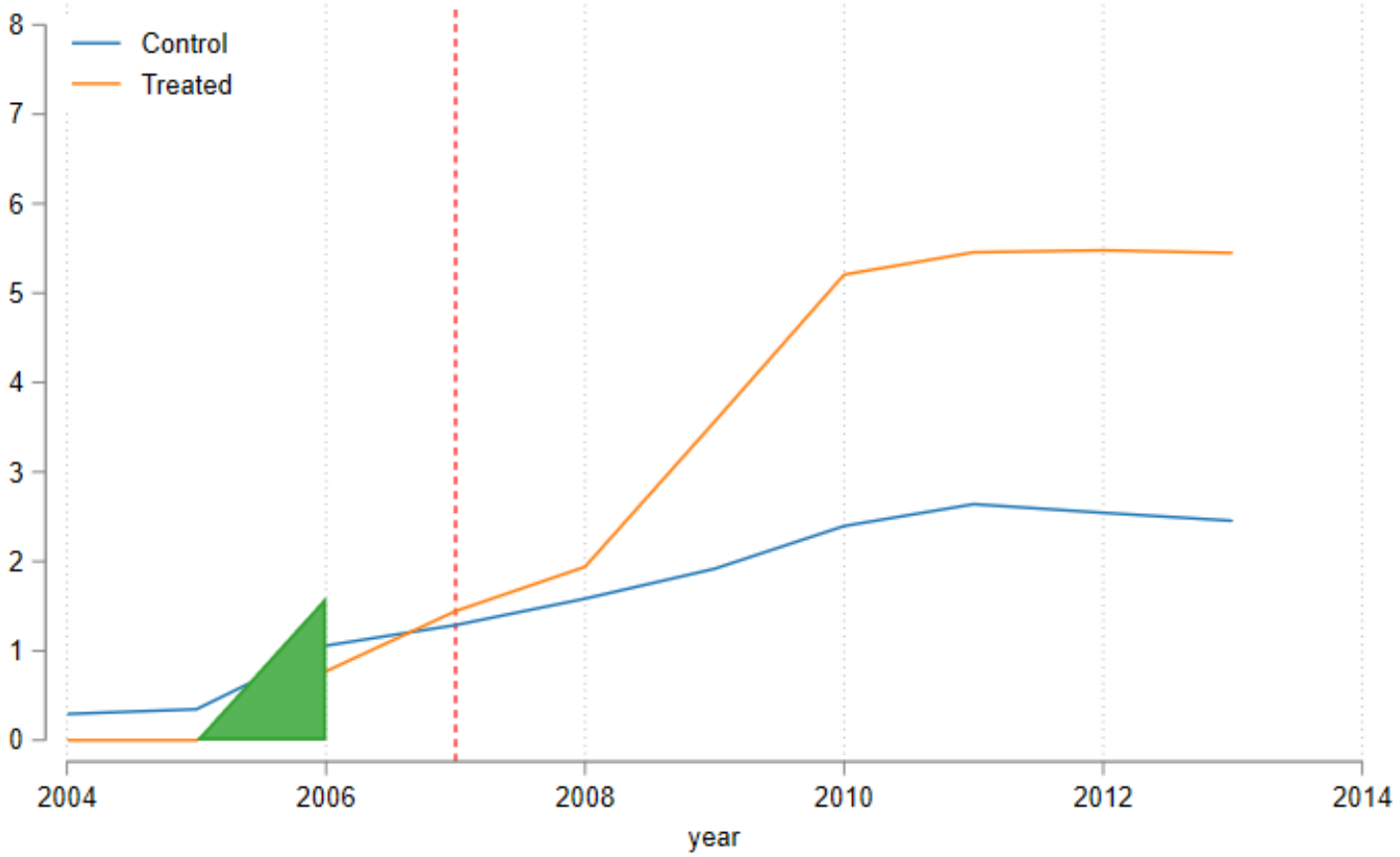
Solar policies raise Solar production (and patenting): Diff-in-Diff Event Study (Callaway & Sant'Anna, 2021, method)



Notes: Difference in Differences; outcomes at the admin2 level (120 cities where ENF firms are located); The mean of the dependent variable is 31.13 MWp; We conduct the estimation on all ENF firms (solar panel and/or cell producers); The number of observations is 1,126; Cell Capacity data is from 2004-2014; Possible year of treatment goes from 2007-2018; We estimate the dynamic ATT's, using all periods relative to the period of the first treatment, across all cohorts; Control group uses only "never treated"; Multiple periods; Callaway and Sant'Anna (2021) estimator; 95% confidence intervals shaded.

Source: Burgess and Van Reenen (2022), Preliminary

Increase in Total Panel capacity after a city is treated in 2007, Time period: 2004-2013



Notes: Estimates of solar policies at city level using SDID (AAHIW, 2021). Dependent variable is log(Solar Panel Capacity). No controls. 2007 treatment only

Increase in Total Number of Solar Cell firms after a city is treated in 2007, 2004-2013