Ray of Hope? China and the Rise of Solar Energy

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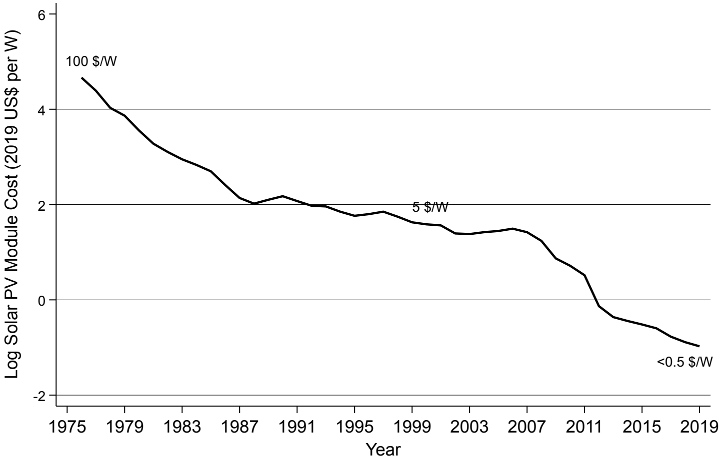
Motivation

Growing need for clean energy

- Around 73% of global greenhouse gas emissions are attributed to the energy sector
- Many emissions cuts rely on further electrification (transportation, heating...)
- Many people around the world do not yet have access to electricity. Emissions will grow if this energy is produced in a carbon-intensive way
- **But where does all this clean energy come from?**

Cost of solar has fallen dramatically

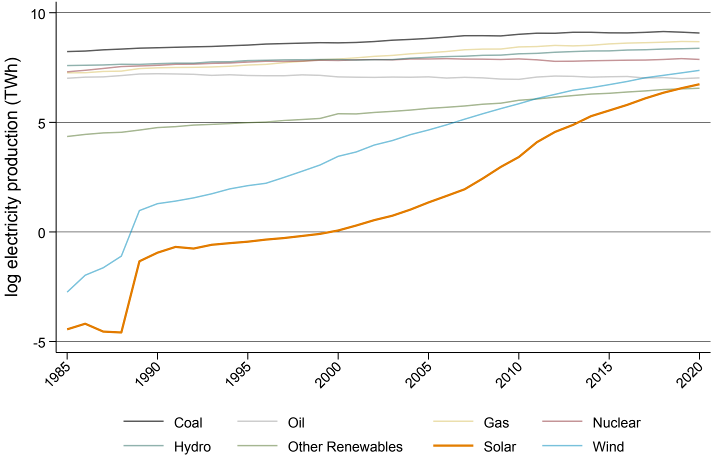
Figure: Global average price of solar PV modules (in 2019 US$ per Watt)



Source: LaFond et al. (2017) & IRENA Database

Renewable electricity capacity, especially solar, has grown rapidly

Figure: World electricity production by source

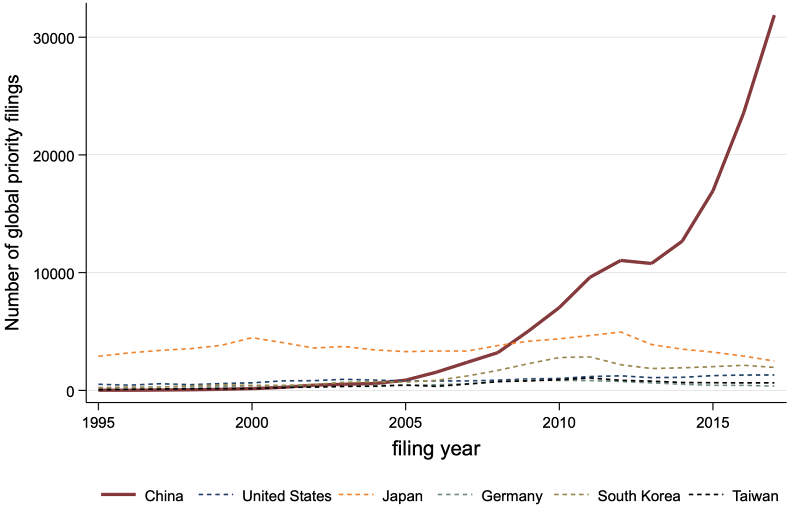


Source: International Energy Agency (IEA)

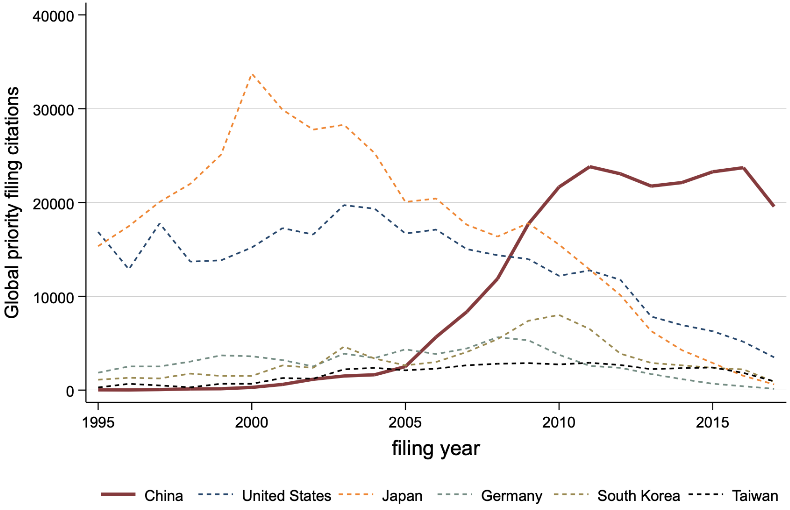
Solar panels production

Solar exports

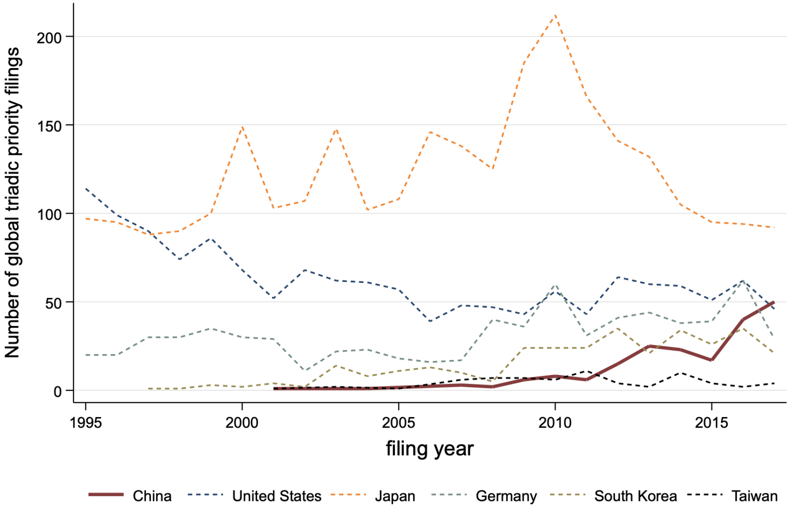
Solar innovation



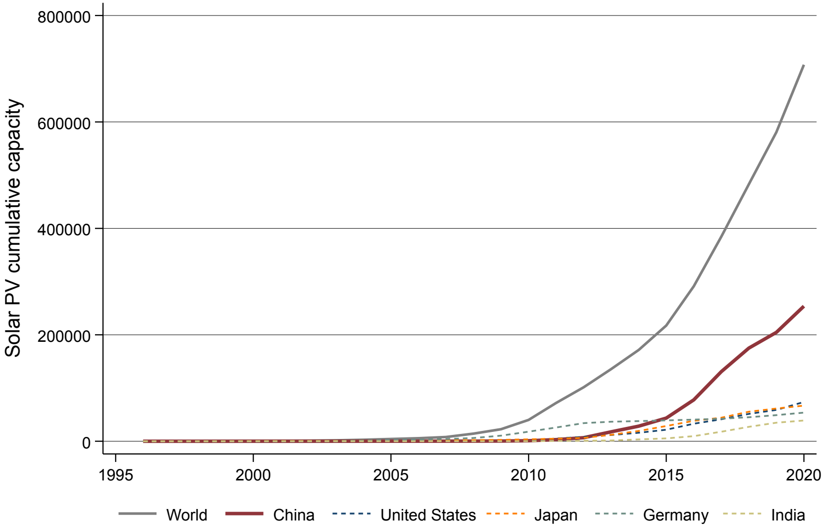
Solar innovation



Solar innovation

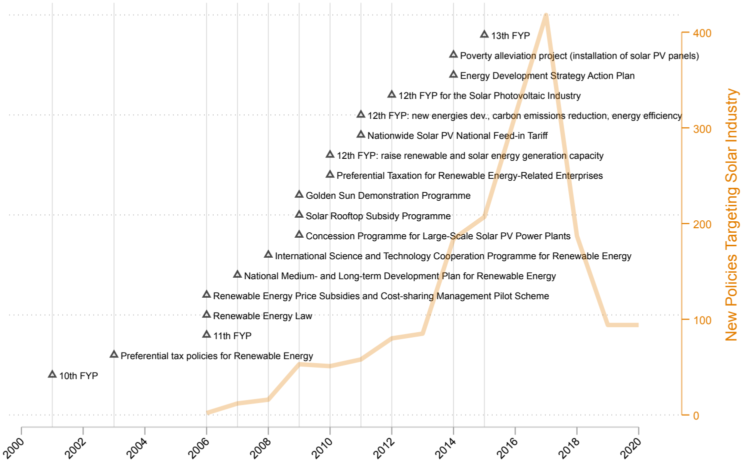


Installed solar PV capacity



China's solar industrial policy ecosystem

Figure: Selected main solar policies & all new solar-related policies (PKULaw data)



5 Year Plans

This paper

- Evaluate contribution of Chinese (place-based) industrial policy to Chinese Solar PV growth
  - US IRA $369 billion clean technologies subsidies (inc. solar) & European Green Deal

[1] Universe of laws and regulations in China (Wang and Yang, 2021)

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- **Findings:** Production and innovation (not so much demand) subsidies generated large increases in solar innovation, productivity, firm numbers, production, revenue and exports

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- Synthetic DID approach (Arkhangelsky et al, 2021) exploiting city-level variation in solar policies
- **Findings:** Production and innovation (not so much demand) subsidies generated large increases in solar innovation, productivity, firm numbers, production, revenue and exports
- Data consistent with new model integrating multi-region energy demand, heterogeneous manufacturers & endogenous R&D and exporting decisions.

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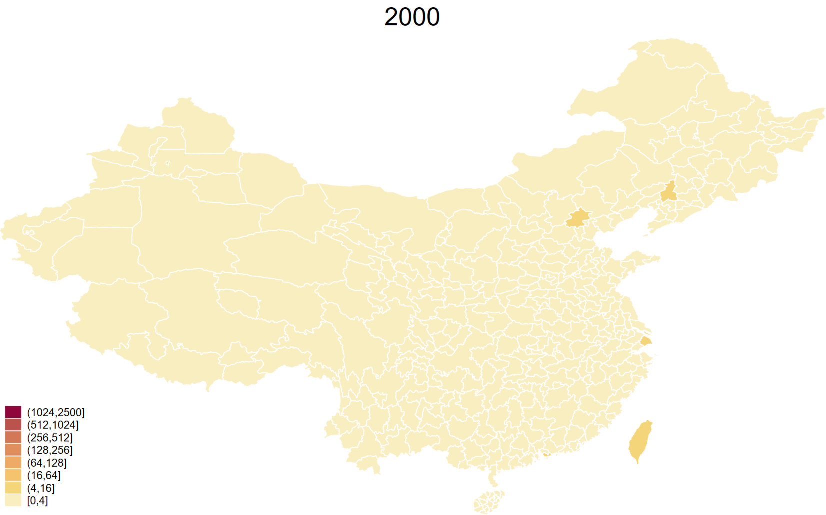
Patent distribution at city level and policy implementation



Note: black circled cities are treated by any subsidy policy

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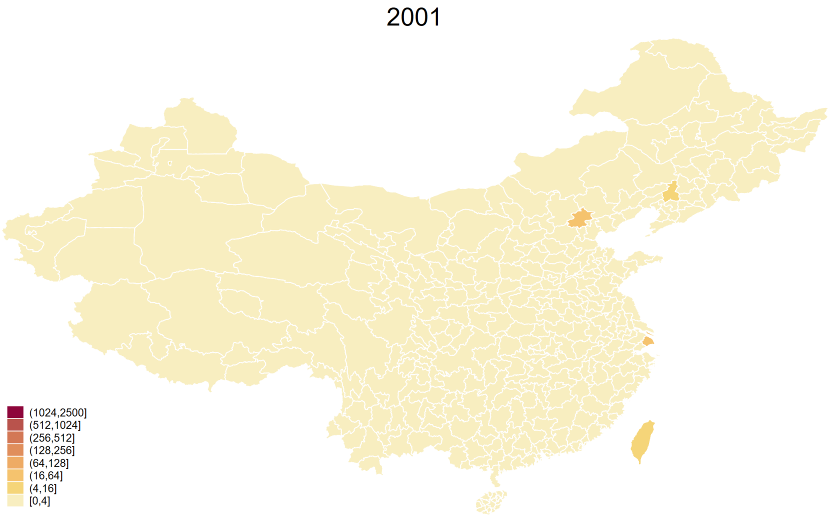

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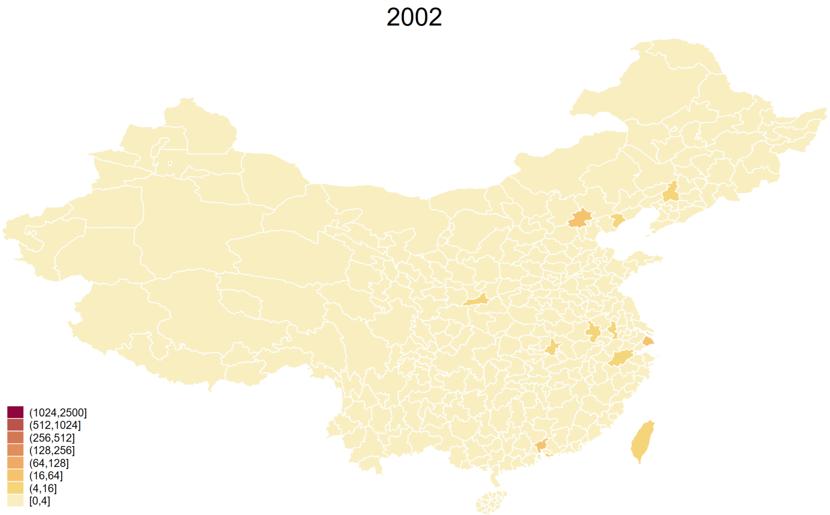

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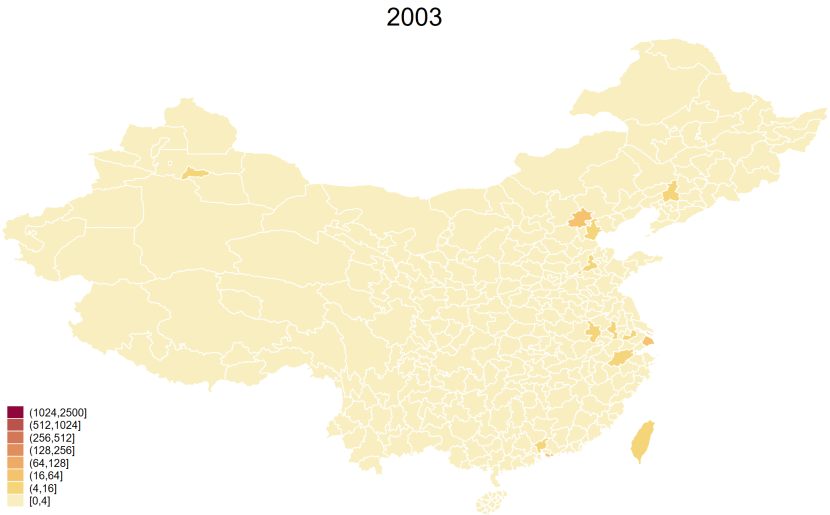

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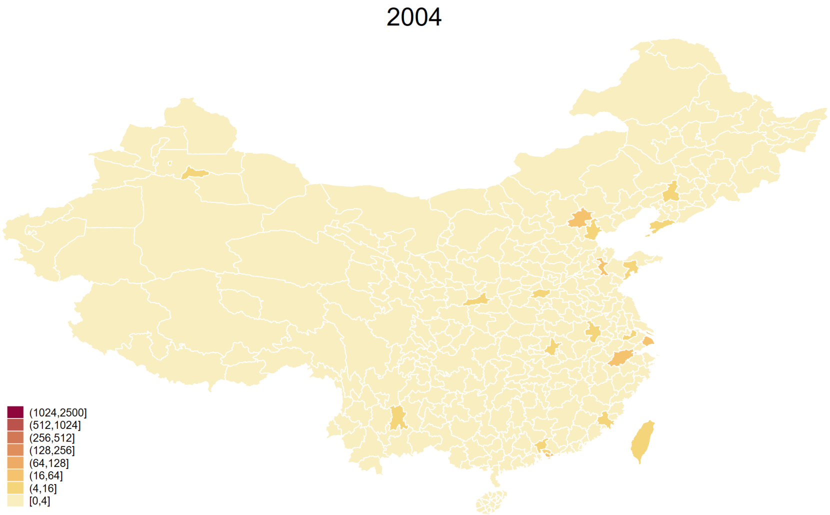

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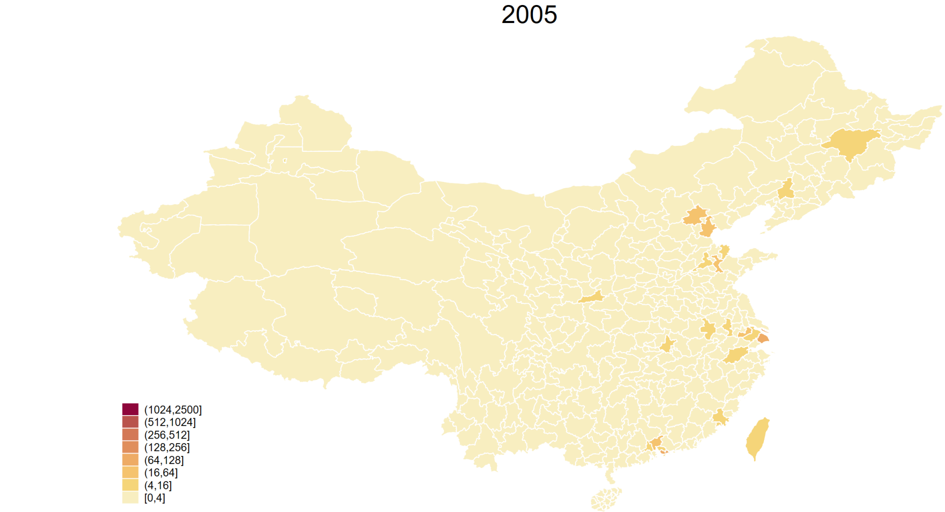

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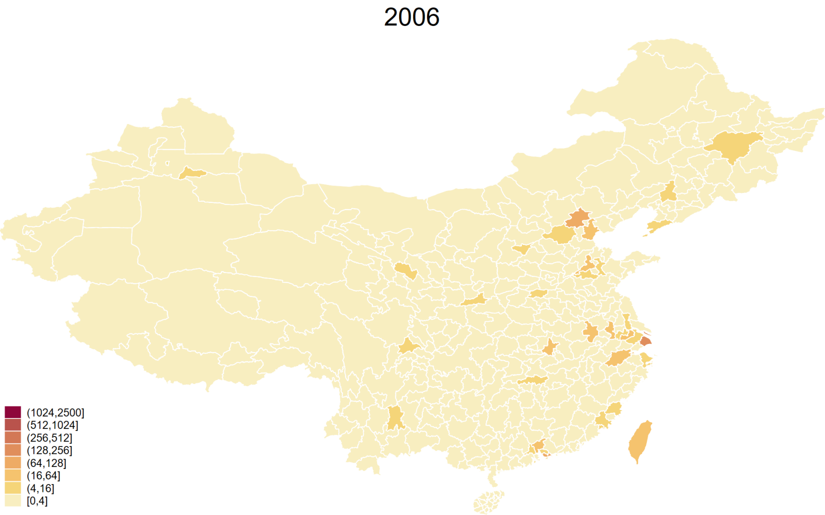

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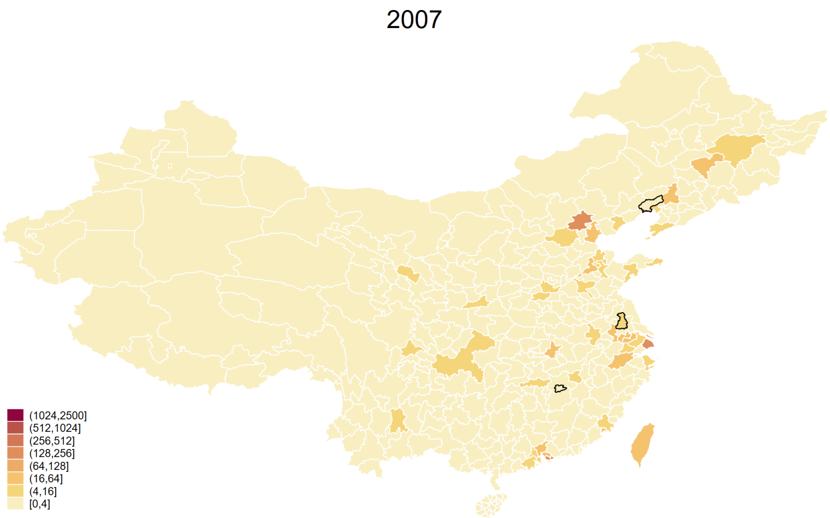

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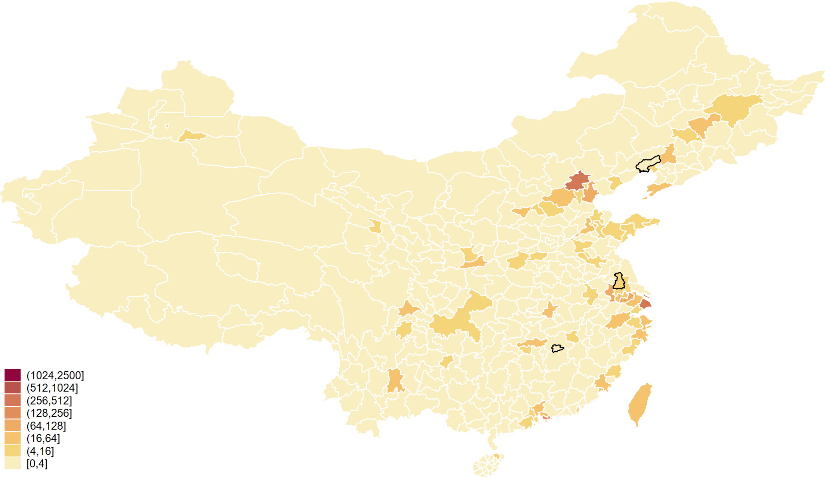
2008



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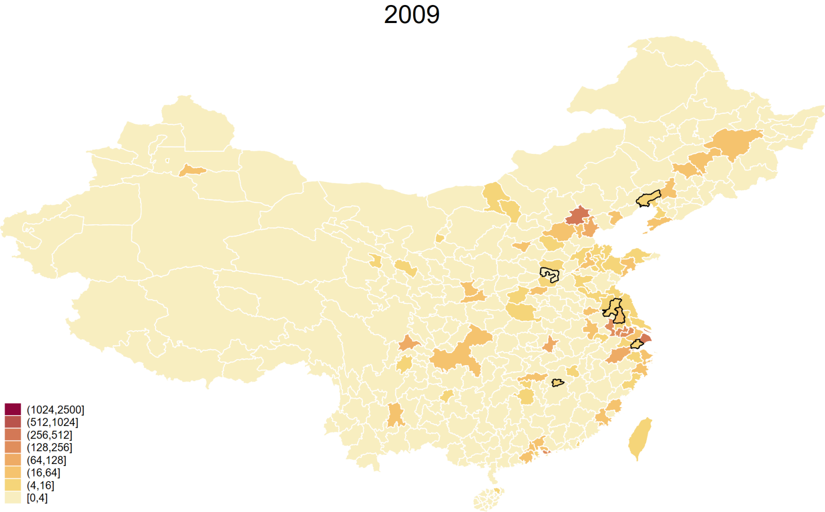

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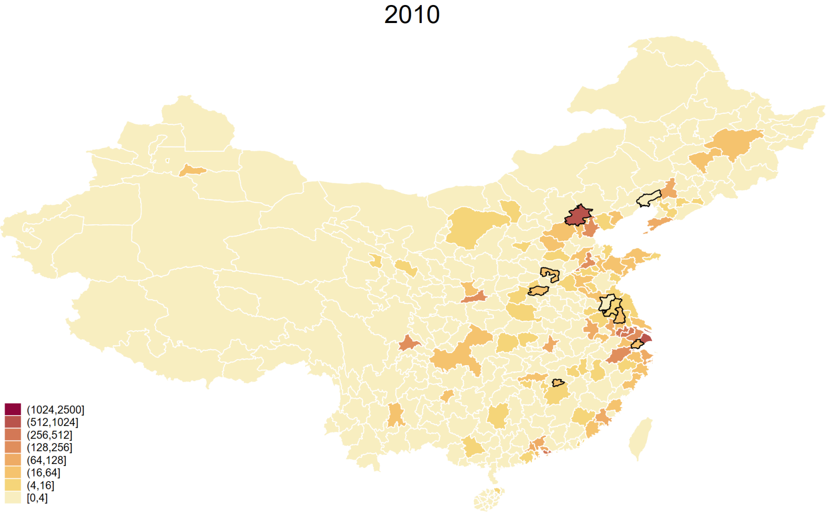

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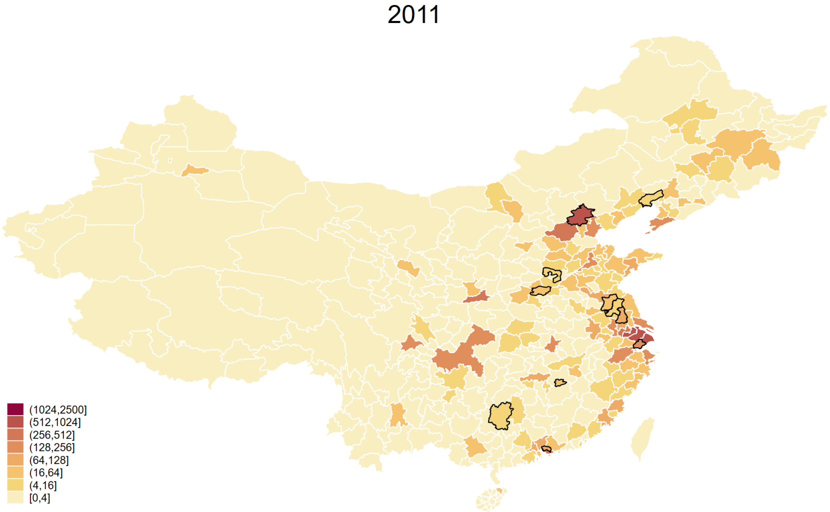

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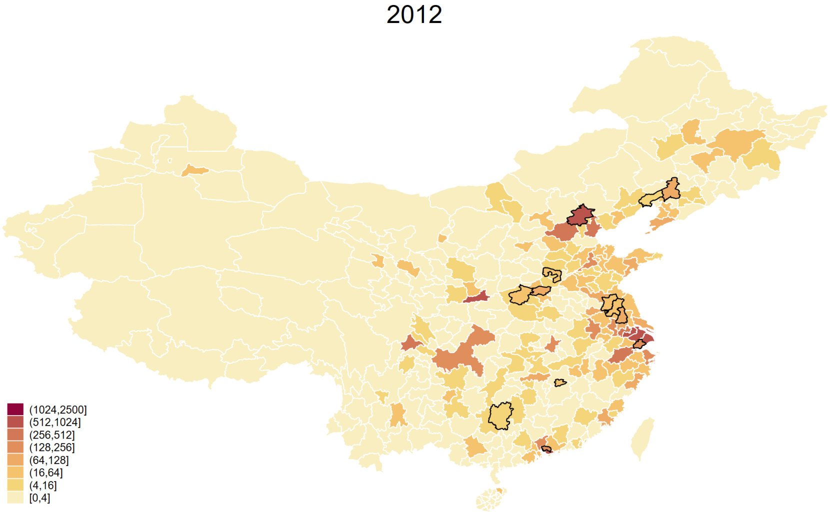

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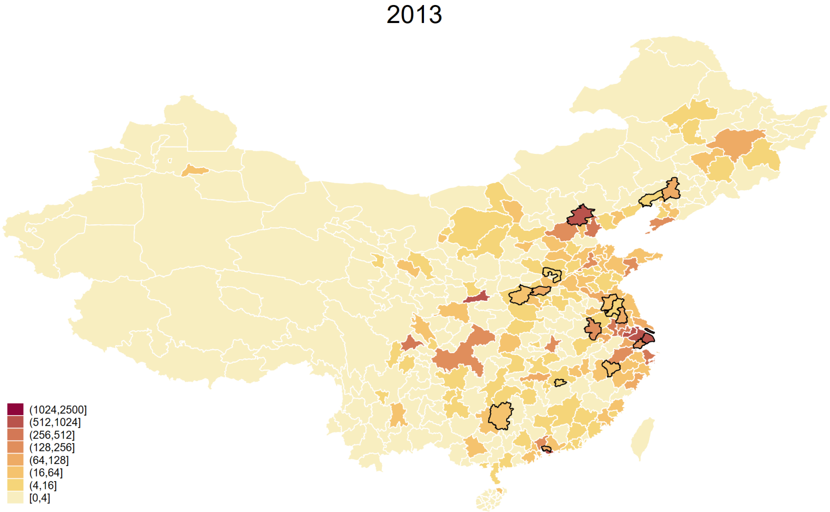

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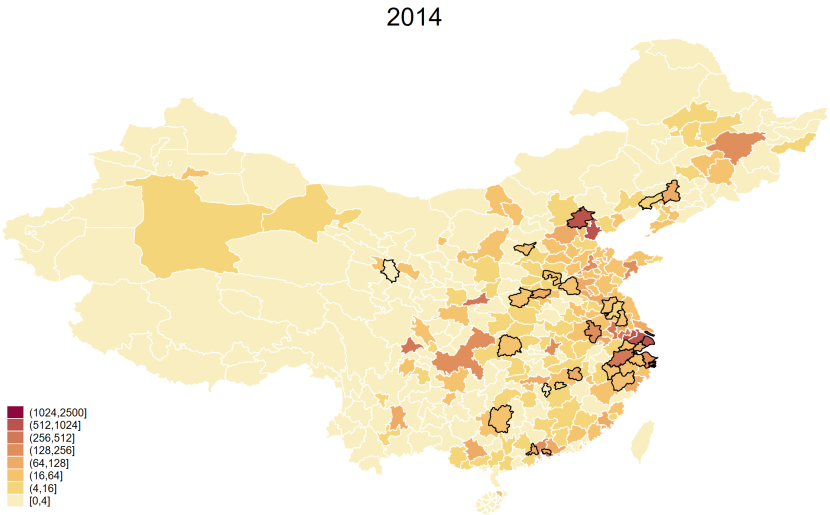

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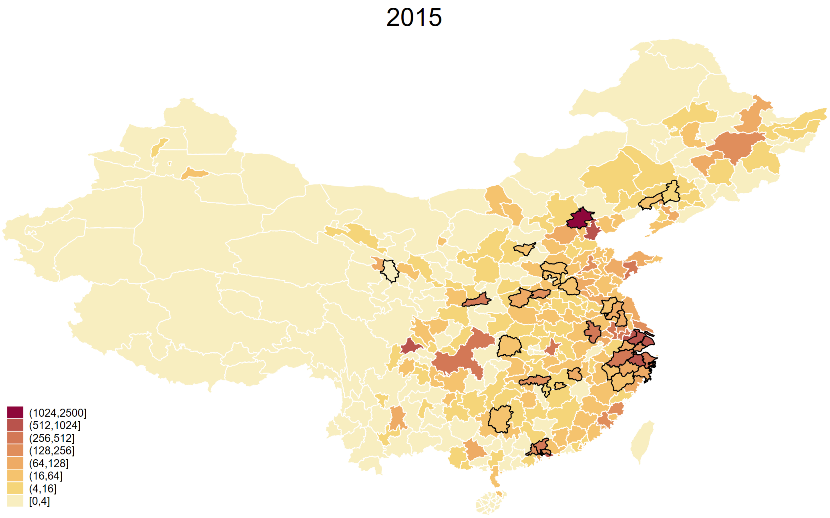

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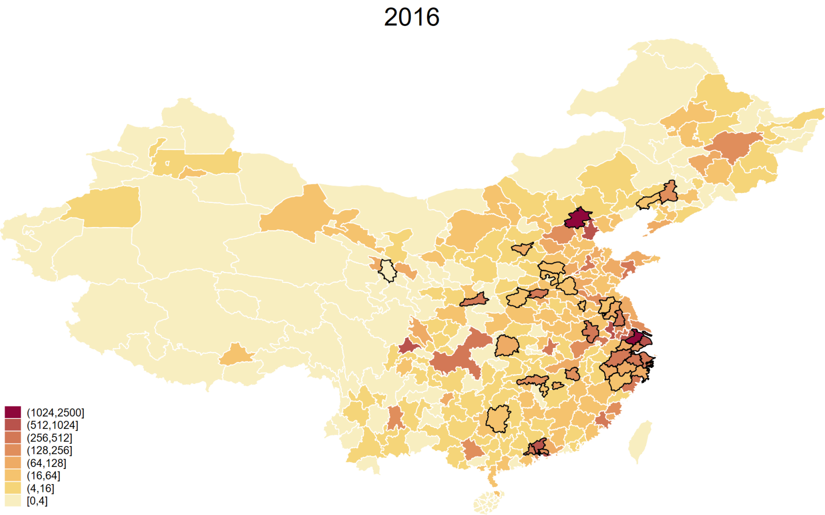

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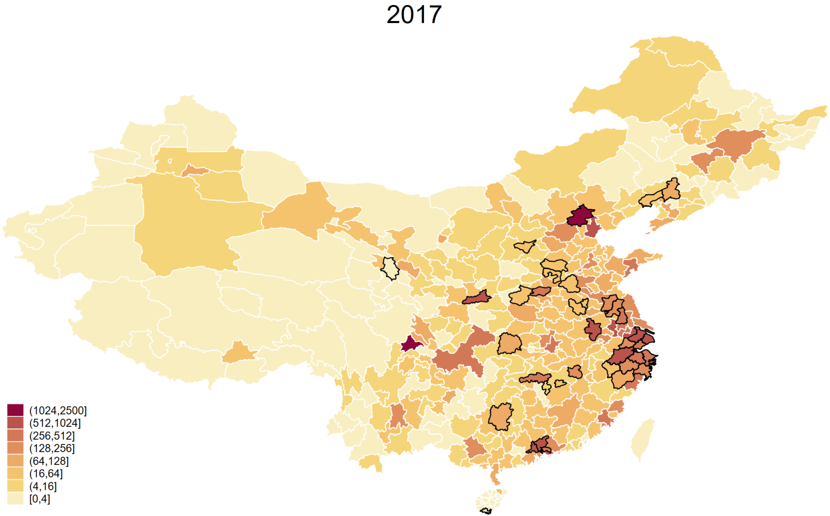

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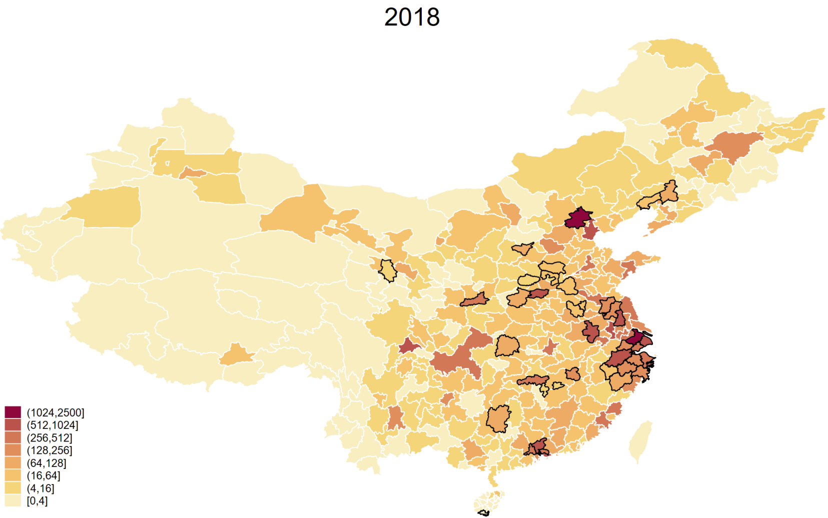

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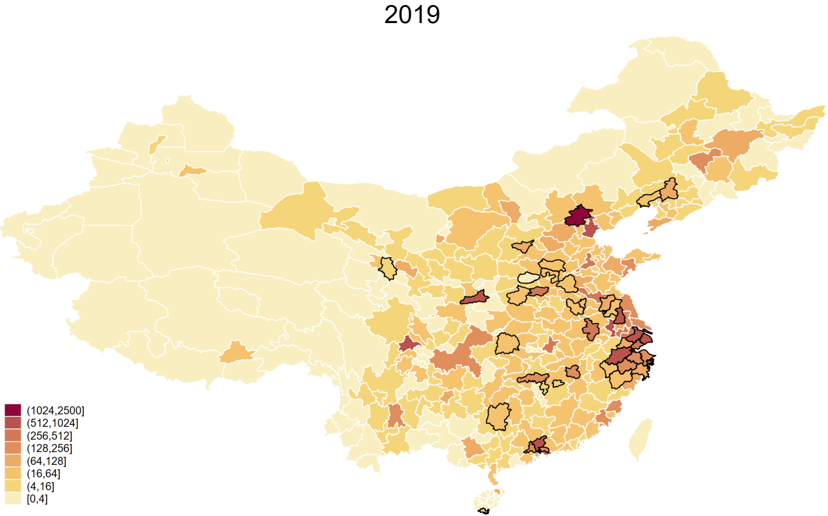

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Data

Multiple sources of firm micro data

- **ENF Register** (Solar Industry Directory): Universe of solar panel and cell manufacturers: 1,718 firms in China 2004-2020
- **SIPO**: All patent filings in China and **PATSTAT** (USPTO, EPO, etc.): Detail on content Example
- **ENF Production Data**: Production and capacity in MWh by firm, 2004-2013
- **BVD Orbis Company Accounts**: Revenue, labor, capital
- **Customs Data**: Exports and imports at HS8 product by firm, 2004-2016
- **Solar Policies**: (detail in next slides)

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- **Matching:** We match all datasets using rich information on firms' contact details (aided by Chinese firm registration platform): name, location, address, telephone, fax, email, website,...

Evolution of Chinese Solar Industry | Descriptive Statistics | Validation with ASIE

Local determination of solar subsidies

Bai, Hsieh, and Song, (2019) on China's special deals:

- Large number of local governments actively support private firms (special deals)
- Enormous administrative capacity to act as a "helping hand" to firms
- They compete to attract and later support businesses
- Combination of special deals and powerful local governments $\rightarrow$ China's economic success?

Local determination of solar subsidies

What we observe in the Chinese solar industry:

- Manufacturing subsidies primarily financed, developed and allocated by local bureaucrats
- Timing, size, and targeting of policy support varied significantly by city[2]
- Tax incentives, discounts for land acquisitions, cheap loans, financial support
- Cities subsidise solar firms' R&D funding, support local labs and research centres
- $\approx 94\%$ of firms are single-city Look at how much the 6% represent in total production

Spatial Concentration

[2] 358 "admin2 regions"

Measuring solar industrial policy

Challenges:

- Intrinsically hard to measure industrial policy
- Retrieving quantitative data on solar subsidies in China is very complicated (International legal disputes - see Ball et al, 2017)

Our approach:

- comment on local IP
- Similar to Lane, 2020 and Juhasz et al, 2022
- Gather the universe of laws and regulations in solar industry from PKULaw dataset
- Analyse all policy documents and classify policies through text analysis
- Distinguish solar subsidies into: (i) Demand, (ii) Production and (iii) Innovation

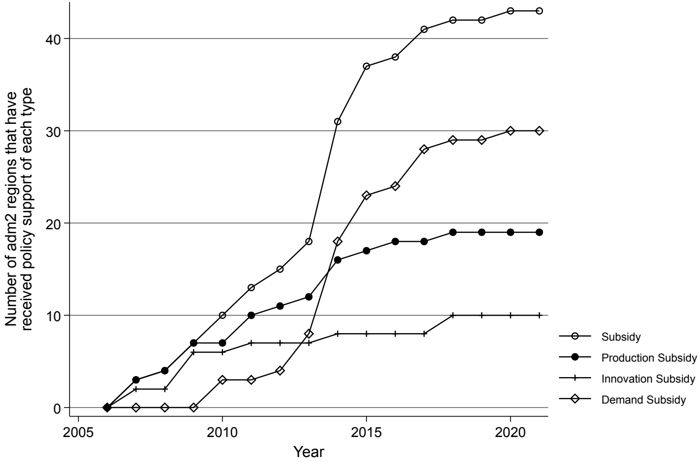
Table: City-level solar policies

Type of policy	Number	key feature	Example
Subsidy	78	Policy text contains precise information on the size of the subsidy	
1. Production subsidy	27	Subsidises solar production	*“The cost of a new solar production line built in Hefei will be subsidized by 12% (2018)”*
2. Innovation subsidy	12	Subsidises solar innovation	*“Firms will be awarded 10,000 RMB if they earn provincial level R&D center certification (Guilin, 2011)”*
3. Demand subsidy	61	Subsidises the installation of solar panels	*“1 RMB per watt for the electricity generated by solar projects installed in Beijing (2010)”*

Source: Own ellaboration using PKULaw data

Time series of policy support

Figure: Number of cities treated with supply & demand subsidies



Empirics

Research Questions

Effectiveness of different solar industrial policy instruments:

- Are **production subsidies** effective at encouraging...
  - patenting, firm count, production, revenue, exports
- Are **innovation subsidies** effective at encouraging...
  - patenting, firm count, production, revenue, exports
- Are **demand subsidies** effective at encouraging...
  - patenting, firm count, production, revenue, exports
- Dynamics: Do effects **persist** over a long time period?

Empirical Strategy

- **Challenges** in evaluating industrial policy
  - Allocation of solar industrial subsidies across firms non-random
  - So we focus on introduction of city-level subsidy **policies**
  - These are staggered over time –first ones in 2007 (encouraged by Eleventh Five Year Plan)
  - Policies could still be correlated with future city outcomes, even controlling for observable covariates
- We follow the **synthetic-difference-in-differences (SDID)** methodology (Arkhangelsky, Athey, Hirshberg, Imbens and Wager, 2021)
- **Identification assumption:**

Synthetic-difference-in-differences (SDID)

- **Outcomes:** patents, number of firms, production, revenue, and exports
- **Treatments:** subsidy policies (demand, production, innovation)
- **Variation:** city-level variation in solar policies and their timing

- SDID: Two-way FE regression with time and unit weights

$$\left(\hat{\tau}^{\text{sdid}}, \hat{\mu}, \hat{\alpha}, \hat{\beta}\right) = \underset{\tau,\mu,\alpha,\beta}{arg\,min} \left\{ \sum_{i=1}^{N} \sum_{t=1}^{T} \left(Y_{it} - \mu - \alpha_i - \beta_t - W_{it}\tau^{\text{sdid}} \right)^2 \hat{\omega}_i^{\text{sdid}} \hat{\lambda}_t^{\text{sdid}} \right\}$$

- Unit weights ω_i: chosen so that average pre-treatment outcome for control units is $\approx$ parallel to pre-treatment outcome for treated units
- Time weights λ_t: more weight on time periods which better predict post-treatment outcomes for control

SDID Intuition

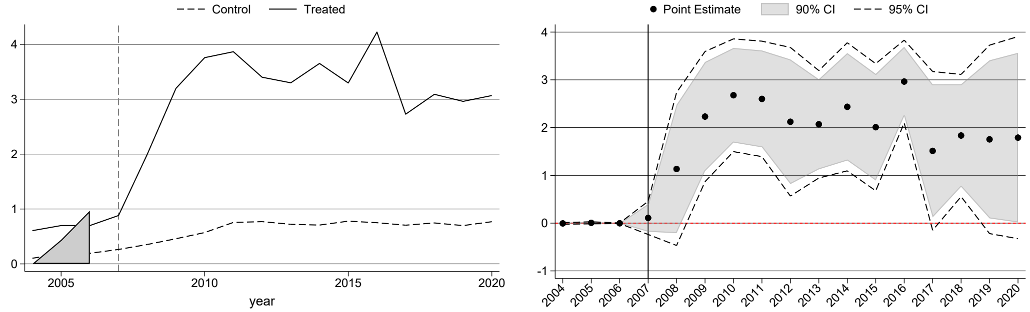
1. Construct synthetic control (SC) group such that pre-trends are approximately parallel
2. Compute treatment effect using DID (with time weights) between treatment and SC

- Allows us to relax the parallel trends assumption
- Comparison with TWFE
  - Generalisation that allows weighting the control group to construct a better counterfactual
  - We use cohort-by-cohort estimation approach, with never treated as control group
  - We aggregate all these cohort estimates to obtain one aggregate ATT for each type of policy

Results

Results

Figure: Patents (2007 Cohort)



Notes: SDID estimates on 358 cities, 3 that introduced policy in 2007. Outcome: IHS of patents by solar firms in a city-year. SE cluster bootstrapped by city.

raw 2013

Results

Table: Patents (Aggregate ATT)

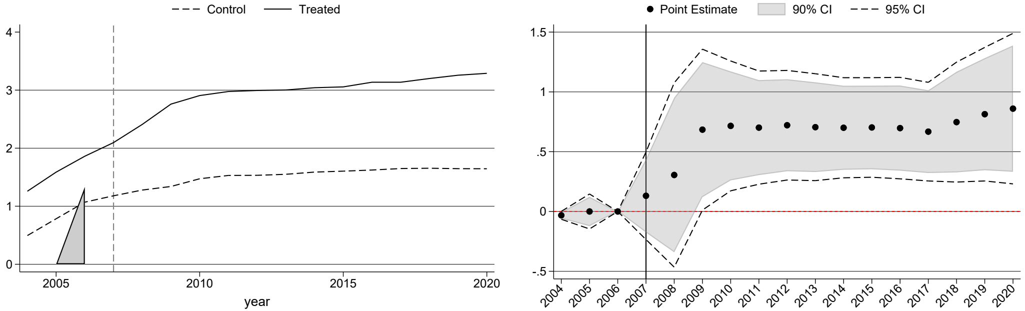
	Any subsidy	*Demand subsidy*	*Production subsidy*	*Innovation subsidy*
All patents	0.496**	0.236	0.871***	1.060***
	(0.200)	(0.275)	(0.227)	(0.367)
Observations	6,086	6,086	6,086	6,086

Notes: * 0.1 ** 0.05 *** 0.01. SDID on 358 cities 2004-2020. Outcome is IHS of patents by solar firms in a city-year pair (av. = 13.1). SE cluster bootstrapped by city.

raw 2013

Results

Figure: Firm Count - Number of Solar Firms (2007 Cohort)



Notes: SDID estimates on 358 cities, focusing on the 3 that introduced a policy in 2007. Outcome is IHS of number of solar firms in a city-year pair.

Results

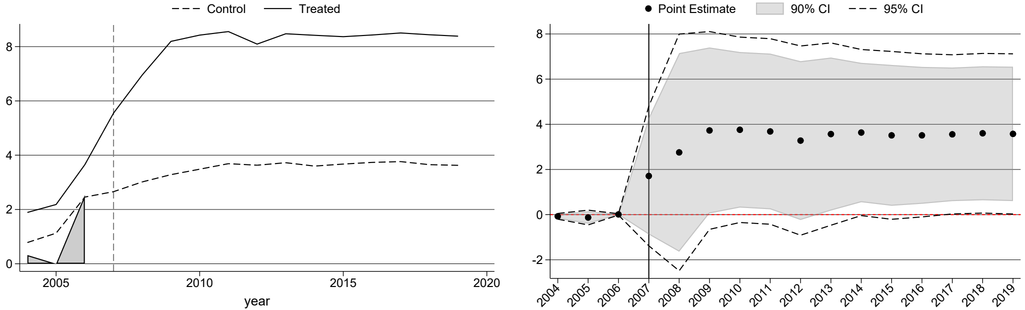
Table: Firm Count - Number of Solar Firms (Aggregate ATT)

	Any subsidy	*Demand subsidy*	*Production subsidy*	*Innovation subsidy*
Firm count	0.186***	0.060	0.288***	0.381***
	(0.064)	(0.043)	(0.090)	(0.135)
Observations	6,086	6,086	6,086	6,086

Notes: * 0.1 ** 0.05 *** 0.01. SDID estimates on 358 cities 2004-2020. Outcome is IHS of count of solar firms in a city-year pair.

Results

Figure: Revenue (2007 Cohort)



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Results

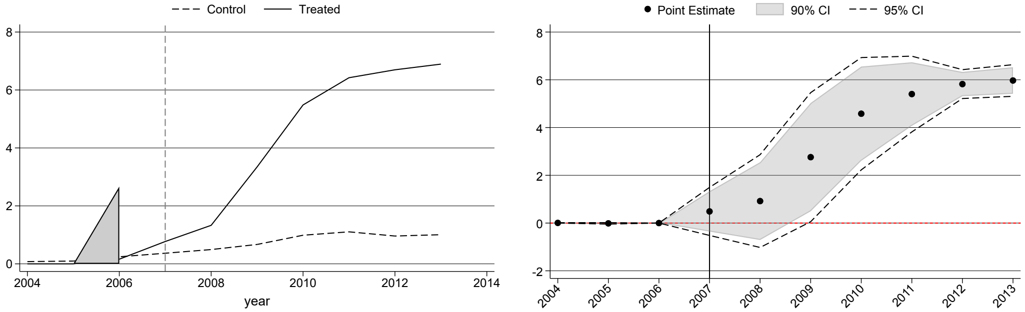
Table: Revenue (Aggregate ATT)

	Any subsidy	*Demand subsidy*	*Production subsidy*	*Innovation subsidy*
Revenue	1.100**	0.192	1.887**	2.670 **
	(0.456)	(0.199)	(0.767)	(1.193)
Observations	5,728	5,728	5,728	5,728

Notes: * 0.1 ** 0.05 *** 0.01. SDID estimates on 358 cities 2004-2019. Outcome is IHS of revenue of solar firms in a city-year pair.

Results

Figure: Panel Production Capacity (2007 Cohort)



Notes: SDID estimates on 358 cities, focusing on the 3 that introduced a policy in 2007. Outcome is IHS of Solar Panel production capacity in a city-year pair.

Results

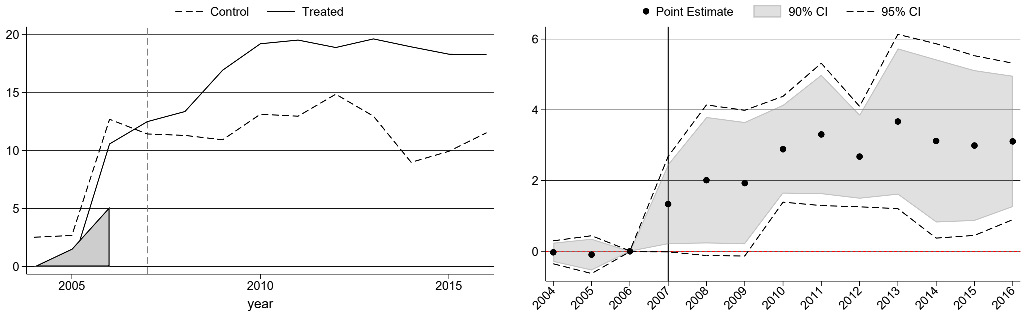
Table: Solar Panel Production Capacity (Aggregate ATT)

	Any subsidy	*Demand subsidy*	*Production subsidy*	*Innovation subsidy*
Panel production	2.098***	0.587	2.496***	2.930***
	(0.532)	(0.467)	(0.575)	(0.773)
Observations	3,580	3,580	3,580	3,580

Notes: * 0.1 ** 0.05 *** 0.01. SDID estimates on 358 cities 2004-2019. Outcome is IHS of production capacity of solar firms in a city-year pair.

Results

Figure: Export Value (2007 Cohort)



Notes: SDID estimates on 358 cities, focusing on the 3 that introduced a policy in 2007. Outcome is IHS of export value of Solar firms in a city-year pair.

Results

Table: Exports (Aggregate ATT)

	Any subsidy	*Demand subsidy*	*Production subsidy*	*Innovation subsidy*
Export value	0.658**	0.095	0.941***	1.404**
	(0.263)	(0.182)	(0.363)	(0.570)
Export volume	2.111**	0.090	2.875**	3.826*
	(0.999)	(0.774)	(1.287)	(1.984)
Solar export value	0.964***	0.311	1.311***	1.917***
	(0.359)	(0.273)	(0.477)	(0.607)
Solar export volume	3.984***	0.980	5.289***	7.501***
	(1.133)	(0.688)	(1.502)	(1.953)

Notes: * 0.1 ** 0.05 *** 0.01. Solar exports classified via HS8. SDID on 358 cities 2004-2016. Outcome is IHS.

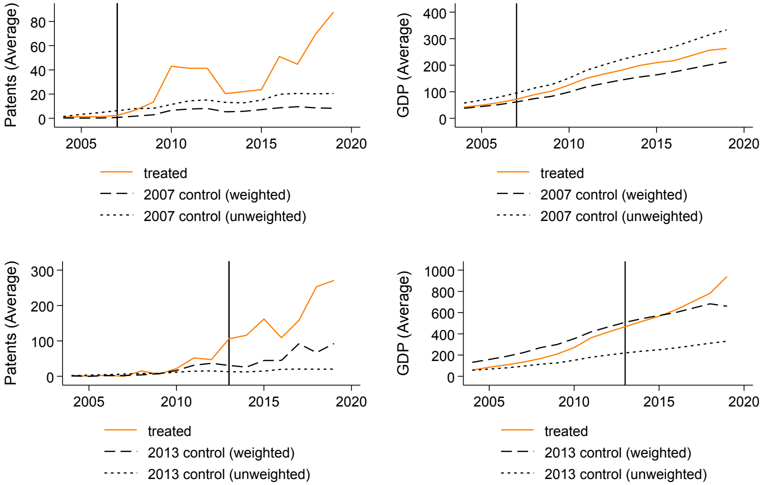
Size of our estimates

SDID suggests that policies increase subsidies by X. How much extra patents and production are we getting for this X according to our estimates? Is it credible?

Size of policy support

Probably wont get a conclusion on this pre NBER

Characterising the control group



Extensions

- Types of patents
  - Different degree of innovation (design, utility, invention) results by type of patent
  - Learning-by-doing results for LBD patents
- Productivity productivity results
- Business stealing vs. agglomeration business stealing results
- Adding controls to SDID specification (GDP, population, income...) results with controls
- Results in levels with 99% winsorisation results in levels

Summary of baseline results

- Subsidies significantly raise solar production, revenue, innovation, exports and number of firms
- Demand subsidies effects are small and insignificant
- Production plus innovation subsidies have the largest impact
- (Next) Consistent with our simple model of:
    - multi-location demand
    - solar PV supply with endogenous innovation and trade

Theory

Model

Summary

- Demand for electricity decided locally (Nested CES)
- A local “Grid Planner” builds **clean and dirty power plants** (e.g. solar vs. coal) using **components** (e.g. solar panels) sourced across **multiple Chinese cities** (subject to transport costs)
- Local **solar manufacturers** have **heterogeneous productivity**.
- They make endogenous **entry, exit, production, exporting, and technology upgrading** (innovation) decisions
- Model provides intuition for differential impact of **differentially targeted place-based subsidies** (installation/demand, production, and innovation) on these multiple outcomes

Timing of Decisions

1. Entrepreneurs pay a sunk entry cost (enter), draw productivity, and decide whether to:
    1. produce (stay in the market)
    2. produce and export overseas
    3. produce, export and innovate
2. Three fixed costs (& associated productivity cutoffs):
    1. production
    2. exporting
    3. innovation
3. Innovation reduces marginal cost of production
4. Producing firms in origin city o serve multiple destination cities d paying iceberg trade costs
5. Demand for intermediates across all Chinese cities (and overseas) from different grid planners influences solar manufacturer decisions

Demand for energy sources

- In each destination city d, representative consumer utility from electricity services e_d:

$$U_d = u\left(e_d\right) \tag{1}$$

- Electricity services installed in each city by Grid Planner, who builds power plants combining output from a clean and dirty energy sector, s and s' (e.g. solar vs. coal):

$$e_d = \left(\kappa_{d,s} e_{d,s}^{\rho} + \kappa_{d,s'} e_{d,s'}^{\rho}\right)^{1/\rho} \tag{2}$$

Demand for energy sources

- Grid planner supplies as much energy as possible in the minimal cost way given income of representative consumer, I_d

$$\max_{e_{d,s}, e_{d,s'}} \left(\kappa_{d,s'} e_{d,s'}^{\rho} + \kappa_{d,s} e_{d,s}^{\rho} \right)^{1/\rho}$$

$$\text{s.t. } P_{d,s} e_{d,s} + P_{d,s'} e_{d,s'} = I_d$$

- Which yields our solar installation demand function, e_s^*:

$$e_{d,s}^* \left(P_{d,s}, P_{d,s'}, I_d \right) = \left(\frac{\kappa_{d,s}}{P_{d,s}} \right)^{\sigma} \frac{I_d}{\kappa_{d,s'}^{\sigma} P_{d,s'}^{1-\sigma} + \kappa_{d,s}^{\sigma} P_{d,s}^{1-\sigma}} \tag{3}$$

Demand for energy sector manufactured inputs (e.g. solar panels)

- To generate output for each energy sector, Grid Planner in city d combines intermediate inputs, $q_{od,s}(\omega)$ = quantity of variety ω manufactured in city o supplied to d using CES:

$$e_{d,s} = \left(\sum_{o} \int_{\omega \in \Omega_{o,s}} q_{od,s}(\omega)^{\frac{\sigma_s - 1}{\sigma_s}} d\omega \right)^{\frac{\sigma_s}{\sigma_s - 1}} \tag{4}$$

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- To meet the optimal energy demand, grid planner chooses solar panels from all cities given their prices, $p_{od,s}$. This will determine price indices $P_{d,s}$ and $P_{d,s'}$.

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- To meet the optimal energy demand, grid planner chooses solar panels from all cities given their prices, $p_{od,s}$. This will determine price indices $P_{d,s}$ and $P_{d,s'}$.
- Solving this constrained optimization problem gives a demand for each variety:

$$q_{od,s}(\omega) = \left(\frac{p_{od,s}(\omega)}{P_{d,s}} \right)^{-\sigma_s} \left(\frac{\kappa_{d,s}}{P_{d,s}} \right)^{\sigma} \frac{I_d}{\kappa^{\sigma}_{d,s'} P^{1-\sigma}_{d,s'} + \kappa^{\sigma}_{d,s} P^{1-\sigma}_{d,s}} \tag{5}$$

Solar Panel manufacturing technology

Production process:

- Firms first need to pay a sunk cost $w_{o,s} f^e_{o,s}$ to operate
- After paying this cost, they draw their production productivity φ, from a Pareto distribution
- To produce, firms use a composite factor of production $L_{o,s}$ with unit cost $w_{o,s}$
- Producing $q_{o,s}(\varphi)$ units of a variety, involves a cost $w_{o,s} f_{o,s} + \frac{w_{o,s} q_{o,s}}{\varphi}$, where:
    - $f_{o,s}$: fixed cost
    - $\frac{1}{\varphi}$: marginal cost

Innovation/technology upgrading:

- Upon observing its initial productivity φ, a firm can upgrade its technology (innovate)
- By incurring a fixed cost: $\eta_{o,s} f_{o,s}$, with $\eta_{o,s} > 1$, it reduces marginal cost to: $\frac{1}{\xi_{o,s}\varphi}$, with $\xi_{o,s} > 1$

Exporting

- Firms can sell to grid planners in China and overseas: both are subject to iceberg trade costs:
  - In order to serve a market d, firm in o needs to produce $\tau_{od,s} q_{od,s}(\varphi)$ of variety, $\tau_{od,s} \geq 1$.
- There is a market access fixed cost for selling overseas (but not within China)
  - In order to serve overseas firm in o pays fixed cost $w_{o,s} f^{x}_{od,s}$

Optimal pricing

- Manufacturers' optimal prices are a constant markup over marginal costs

$$p_{od,s}(\varphi) = \frac{\sigma_s}{\sigma_s - 1} \frac{w_{o,s}\tau_{od,s}}{\xi_{o,s}\varphi} \tag{6}$$

Optimal profits

Industry equilibrium

Characterisation of the solution

- We can characterise the solution in terms of three productivity cut-offs
  - Least productive firms exit
  - Next most productive firms sell only in China and do not innovate
  - Next most productive firms also export
  - Highest productivity firms export and innovate optimal profits

- Equilibrium involves solving for vector of price indices for clean and dirty energy in each city
- Note: We take general level of city level prices and wages as given (not full GE as solar only one sector)

Solar industrial policy

1. **Production subsidies**
   - We model production subsidies s, as a reduction in input costs for manufacturers, whose marginal cost becomes $\frac{1-s}{\varphi}$.
2. **Innovation subsidies**
   - We model innovation subsidies, ϕ as a reduction in the fixed costs of technological upgrading, which becomes $\phi(\eta_{o,s} f_{o,s})$, with $\phi < 1$
3. **Demand/Installation subsidies**
   - We model solar demand subsidies as θ_d, shifting $e_d = \left(\kappa_{d,s'} e^{\rho}_{d,s'} + \theta_d \kappa_{d,s} e^{\rho}_{d,s}\right)^{1/\rho}$

Comparative statics

- All outcome variables and subsidy policies measured in origin city o

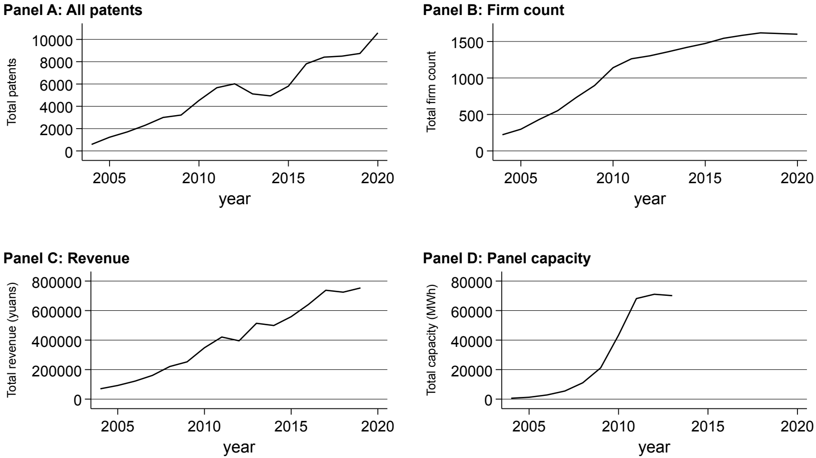
	Demand Subsidy, θ_o	*Production Subsidy, s_o*	*Innovation Subsidy, ϕ_o*	*Production & Innov. Subsidy, $s_o + \phi_o$*
Innovation$_o$	+ / 0	+	++	+++
Firm count$_o$	+ / 0	++	+/0	++
Revenue$_o$	+ / 0	++	+	+++
Panel production$_o$	+ / 0	++	+	+++
Exports$_o$	+ / 0	++	+	+++

Notes: A "+" denotes the strength of a relationship, so "+++" is strongest and "+/0" the weakest (positive) relationship

Conclusions and next steps

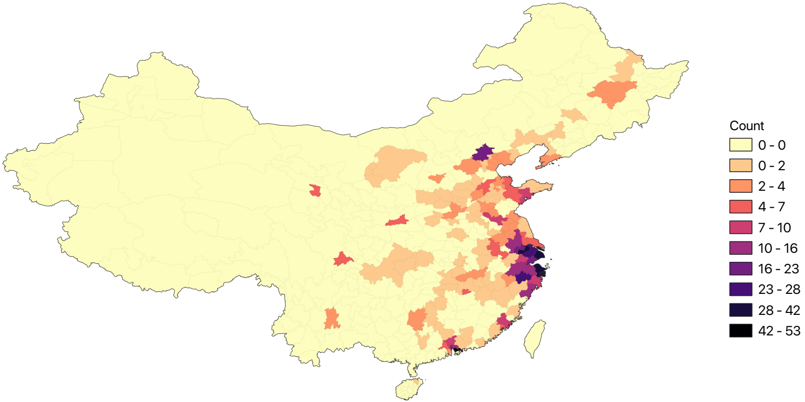
Appendix

Chinese Solar industry evolution



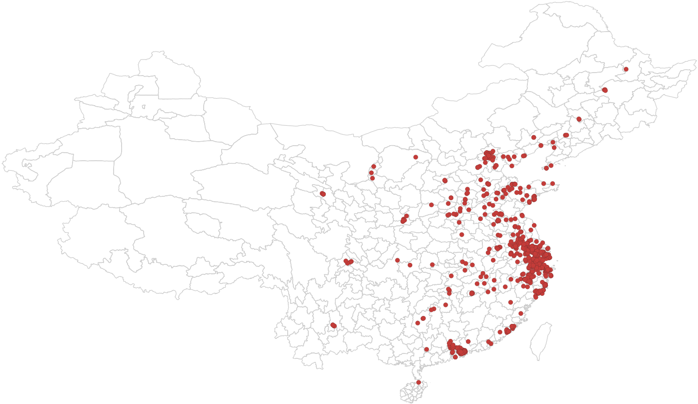
Notes: Time series for total number of patents filed by solar firms at the SIPO; firm count obtained from the Chinese firm registration platform; revenue obtained from Orbis and panel capacity, obtained from ENF Market Research reports. The sample is our near-universe of solar panel manufacturers in China, obtained from ENF's register.

Spatial concentration of the Chinese solar industry



Raw Coordinates

Spatial concentration of the Chinese solar industry



Solar PV in the Chinese government's Five-Year Plans

- **2001-2005 Tenth Five-Year Plan:**
  - Solar a targeted sector for first time, together with other renewable energies.
  - In 2001 no solar industry.
  - In 2005 considerable growth.
- **2006-2010 Eleventh Five-Year Plan:**
  - Solar industry as an opportunity to attain technological leadership.
  - Included funding for R&D and manufacturing development for the first time.
  - Solar industry witnessed exceptional growth
- **2011-2015 Twelfth Five-Year Plan:**
  - Government kept pushing for solar adoption, supply-chain expansion and indigenous R&D.
  - R&D goals gained in detail and scope
- **2016-2020 Thirteenth Five-Year Plan:**
  - Targeting capacity and R&D expansion, as well as industry-wide cost-reduction.
  - Includes Thirteenth Five Year Plan for Solar Energy Development.

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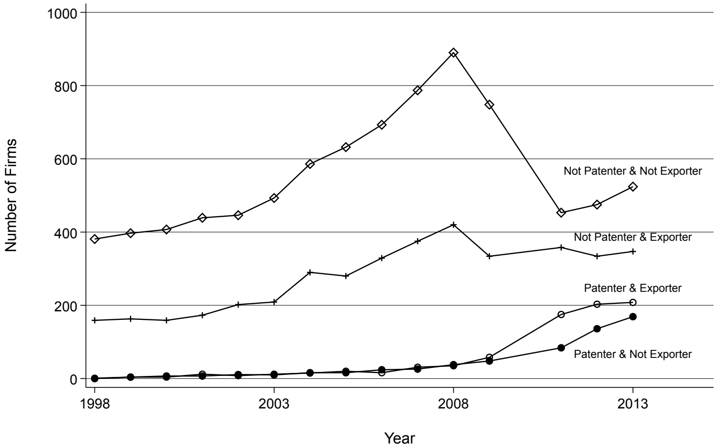
The productivity thresholds in the data

Figure: Number of firms (ASIE) in each group

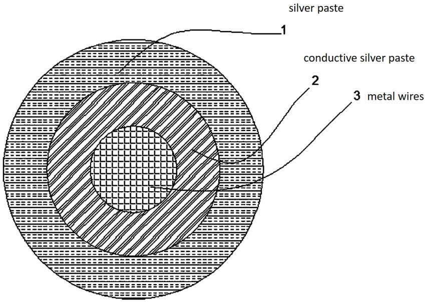


Note: Firm-level data from ASIE, merged with SIPO.

LBD-Patent: Patent as process innovation

Grid Line Structure for Solar Cell manufacturing (CN104752533A)

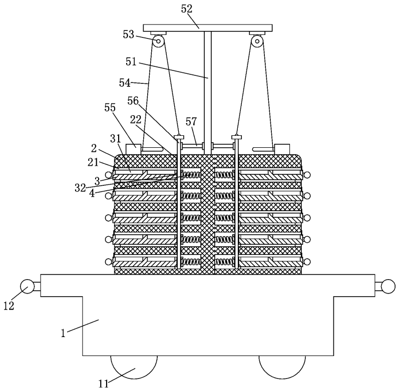
This invention comprises metal wires and conductive silver paste. The grid line is woven from metal wires, with a layer of silver paste applied to the metal wires which ensures excellent adhesion between the silver paste and the metal wires as well as strong ohmic contact between the sub-grid line and the silicon wafer. The silver paste used for the main grid line does not contain glass material, which ensures good adhesion between the main grid line and the silicon wafer and reduces the recombination of minority carriers under the main grid line. **Compared with the prior art, the present invention greatly reduces the amount of (expensive) silver paste used generating big cuts in production costs. It ensures excellent aspect ratios of the grid lines, eliminating the possibility of broken lines and false prints, thereby improving the photovoltaic conversion efficiency of the solar cell, and being suitable for large-scale industrial production.**



LBD-Patent: Patent as process innovation

Transfer Assembly of a Solar Cell (CN208706675U)

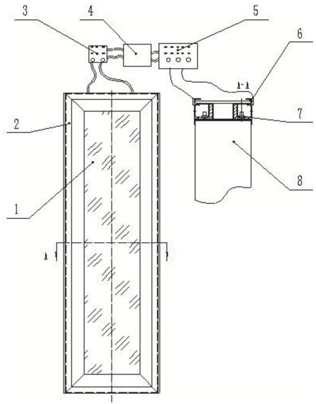
The utility model discloses a transfer assembly of a solar cell piece with a metal-stacked electrode. The assembly comprises a trolley body, a storage member arranged on the top of the trolley body, and a positioning component arranged on the storage member. A plurality of slots are opened on the storage member, and a storage plate is slidably connected in each slot. The top of the storage plate is provided with a groove, a spring is provided on the inner wall of each slot, the spring is connected to the storage plate, a first connecting hole is opened on the storage plate, and a second connecting hole penetrating all the slots is opened on the storage member. The positioning component includes a support column, a crossbar, a pulley, a rope, a motor, a limit rod, and a sliding block. **The utility model delivers the solar cell piece through the newly designed transfer assembly. The structure is simple, easy to install and transport, and will not damage the solar cell piece during transportation, reducing the defect rate and ensuring product quality.**



Non-LBD Patent

Road Cliff Lighting Device (CN212273899U)

This utility model patent relates to a road cliff photovoltaic lighting device, which includes a road cliff stone or road guardrail connected to the outer surface of a photovoltaic component. The photovoltaic component is connected to the inverter and battery through a controller in sequence, and the controller is connected to the light strip. The light strip is located on one side of the road cliff stone or road guardrail facing the center of the road. By combining the photovoltaic power generation system with the road cliff or guardrail lighting, photovoltaic power generation, which serves as green energy, is closely integrated with transportation, solving the power supply and subsequent maintenance problems of traditional road lighting and reducing construction and maintenance costs. It also produces an uninterrupted power supply to indicate the road dividing lines and boundary lines, guiding the passage of vehicles and pedestrians, relieving driving fatigue and beautifying the road.



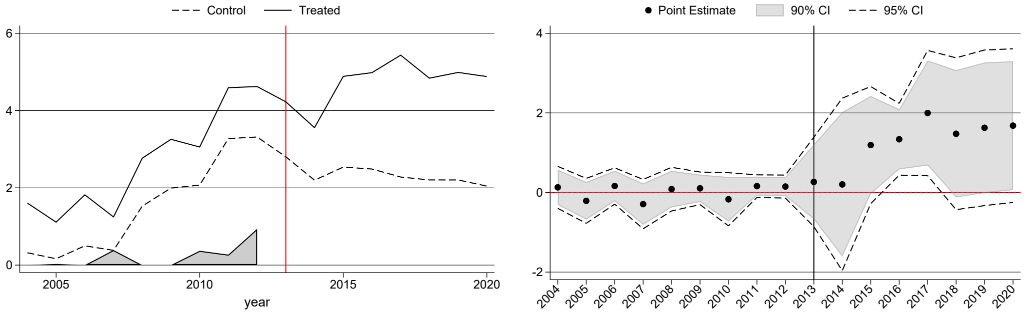
Non-LBD Patent

New Phosphide Material

The present invention provides a carbon-doped P-type gallium phosphide material, in which carbon is used as the doping element of the P-type gallium phosphide semiconductor material. The preparation method of the material is to use metal organic chemical vapor deposition technology, introduce organic gallium source and phosphorus source into the reaction chamber, let them decompose at high temperature, and react on the surface of the substrate to produce gallium phosphide material. During the generation of gallium phosphide material, carbon impurities are introduced by inputting substances containing carbon elements, or by utilising carbon atoms generated by the organic gallium source during thermal decomposition. In the present invention, carbon replaces Mg or Zn. Since carbon doping has a small diffusion coefficient and stable properties, highly doped GaP materials can be produced, which are characterised by high efficiency, low diffusion, and high stability.

Results 2013 Cohort

Figure: Patent (2013 Cohort)



Notes: SDID estimates on 358 cities, focusing on the 3 that introduced a policy in 2013. Outcome IHS of patents by solar firms in a city-year. SE cluster bootstrapped by city.

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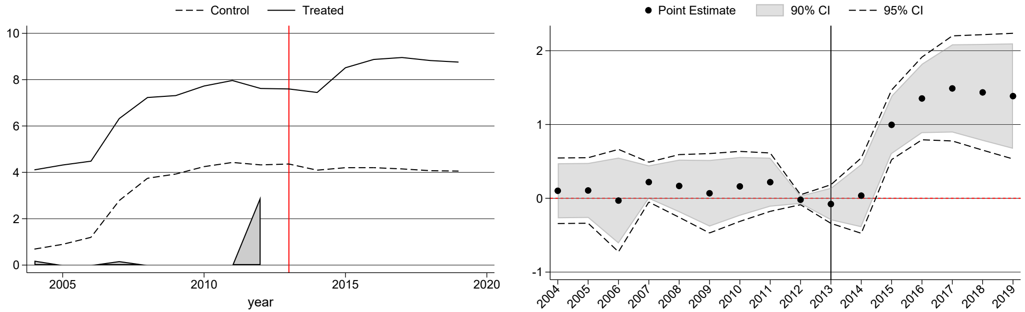
Results 2013 Cohort

Figure: Revenue (2013 Cohort)



Notes: SDID estimates on 358 cities, focusing on the 3 that introduced a policy in 2013. Outcome is IHS of revenue of solar firms in a city-year pair. SE cluster bootstrapped by city.

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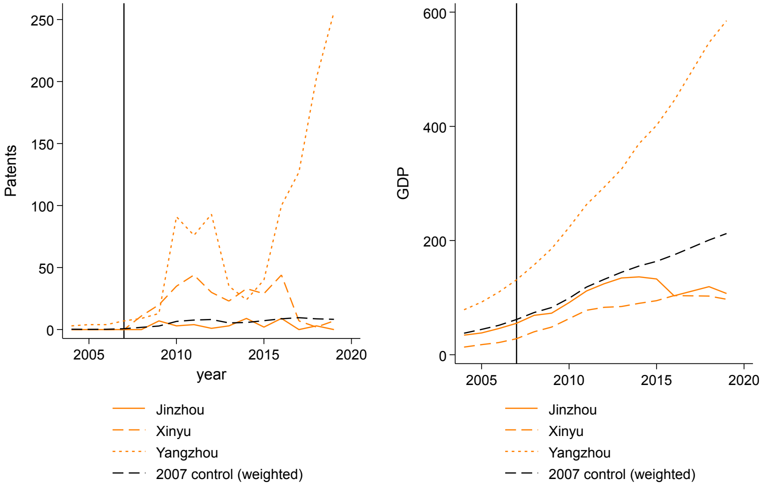
Characterising the control group



Results

Table: Examining different types of patents (Aggregate ATT)

	Any subsidy	*Demand subsidy*	*Production subsidy*	*Innovation subsidy*
All patents	0.496**	0.236	0.871***	1.060***
	(0.200)	(0.275)	(0.227)	(0.367)
□ Design patents	0.186	0.277	0.237	0.151
	(0.138)	(0.216)	(0.173)	(0.253)
□ invention/utility model patents	0.529***	0.201	0.937***	1.097**
	(0.201)	(0.274)	(0.232)	(0.373)
• Solar patents	0.515***	0.189	0.857***	1.090**
	(0.168)	(0.210)	(0.216)	(0.358)
• Non-solar patents	0.247	-0.034	0.732***	0.809ˆ**
	(0.168)	(0.196)	(0.203)	(0.320)

Notes: * 0.1 ** 0.05 *** 0.01. Solar patents are classified according to IPC codes

Results

Table: Learning-by-doing Patents (Aggregate ATT)

Results

Table: Productivity (Aggregate ATT)

Results

Table: Positive Spillovers, not Business Stealing

	(1) All patents	(2) Firm count	(3) Revenue	(4) Panel capacity
Any subsidy in an adjacent city	0.373***	0.099	0.485***	0.385
	(0.096)	(0.055)	(0.177)	(0.263)
Observations	5,049	5,049	4,768	3,210

Notes: * 0.1 ** 0.05 *** 0.01. Treated cities are those contiguous to those introducing a policy. SDID estimates.

Results

Table: Controlling for GDP per capita

Results

Table: Levels results