Quantitative Policy Analysis

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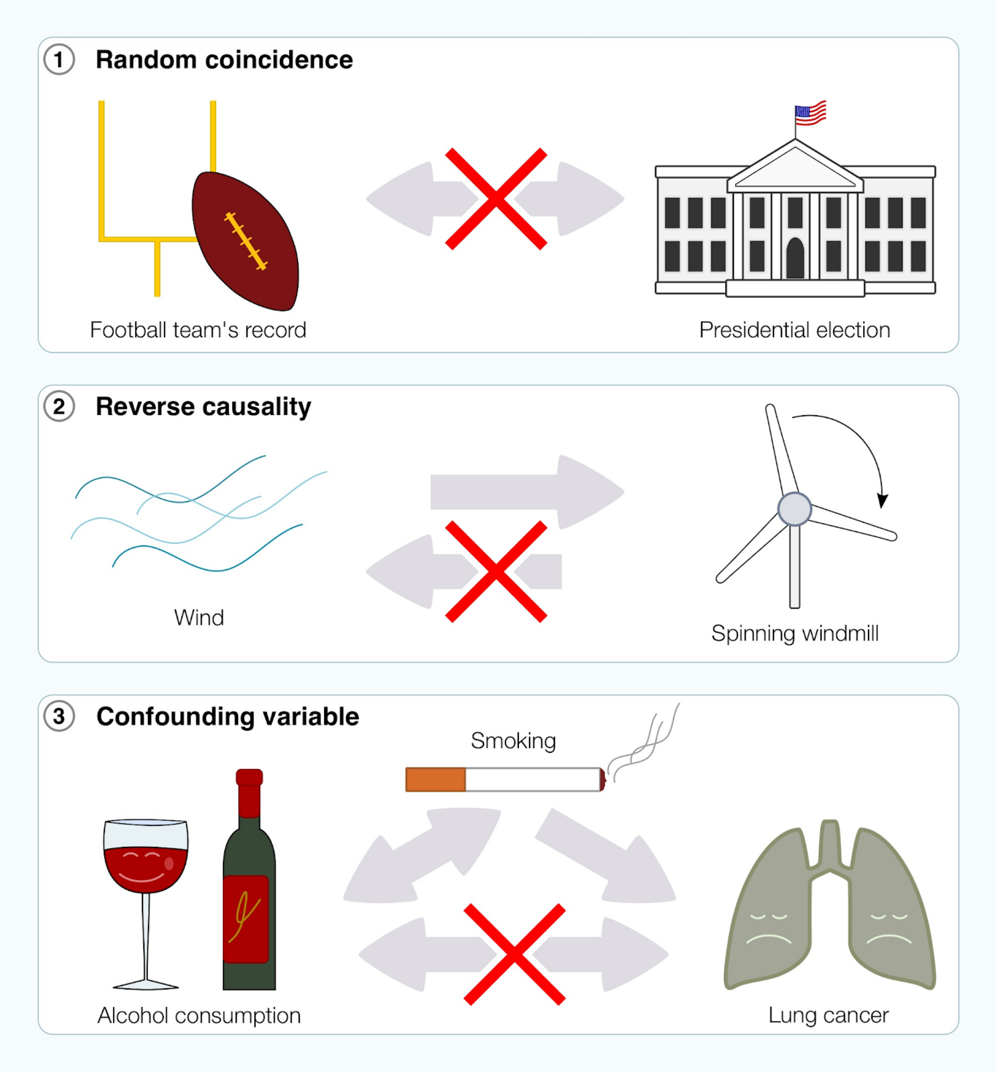
Agenda

- Why do policy analysis?
- Energy storage mandates in California
  - Goals
  - Methods
  - Results
- Interconnection policy reforms in Massachusetts and New York
  - Goals
  - Methods
  - Results
- Conclusions

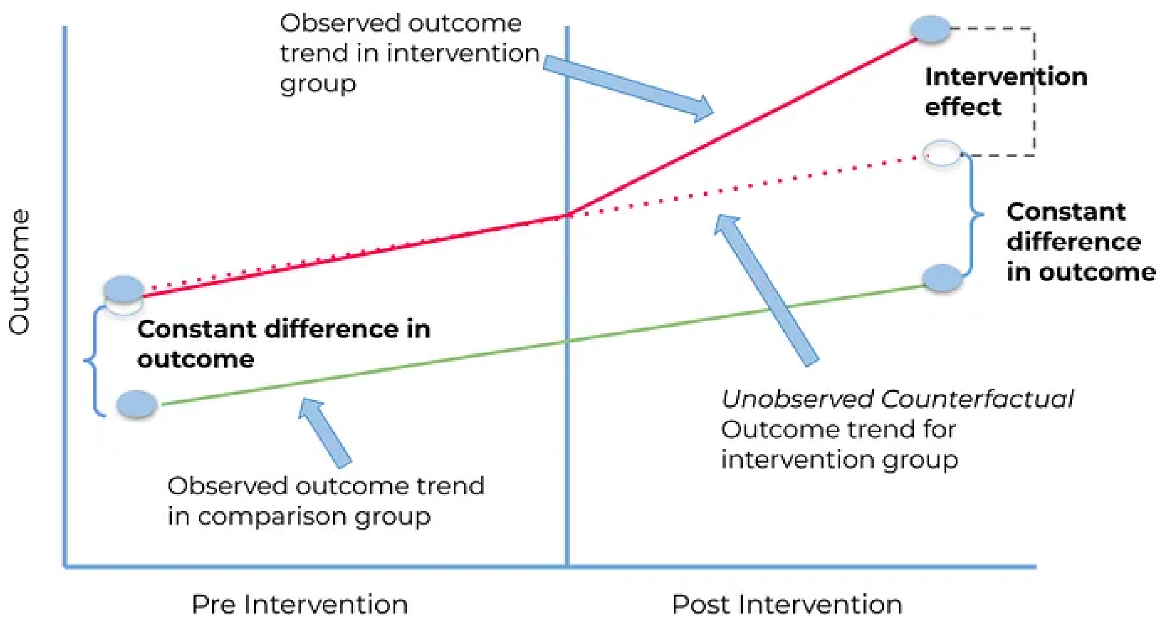
Why do policy analysis?



Source: Chen, 2021

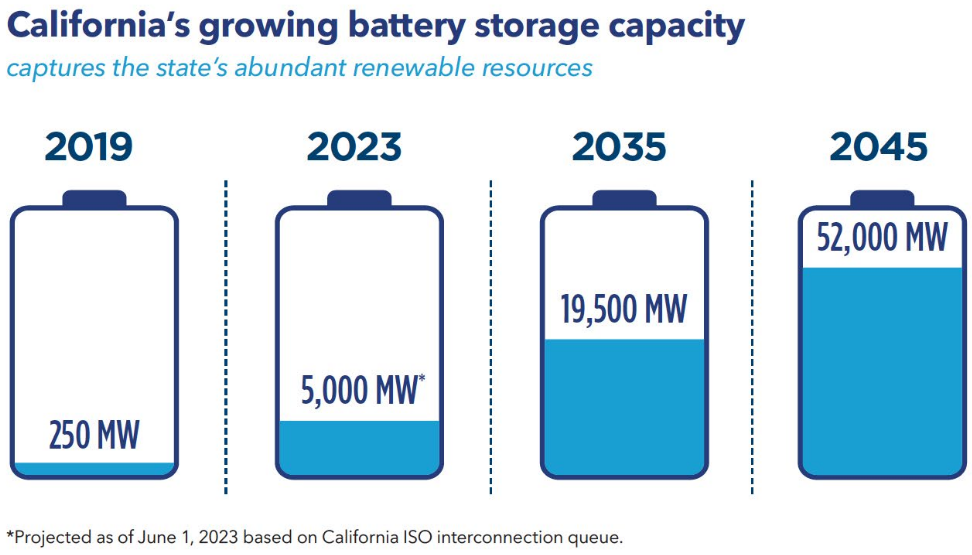
- The electricity sector is one of the most heavily regulated sectors in the world
  - Policy will have a tremendous impact on how and where energy storage is deployed
- Just because a policy is implemented does not mean its necessarily effective
  - Correlation does not equal causation
- Thinking scientifically about policy lets us know what interventions are effective and should be replicated

Thinking scientifically about policy



- Unlike physical scientists, social scientists cannot create a control group for testing
- Social scientists do use RCTs, but they are unhelpful for explaining macro changes
- Econometrics can help us develop a counterfactual and understand if results are causal of spurious

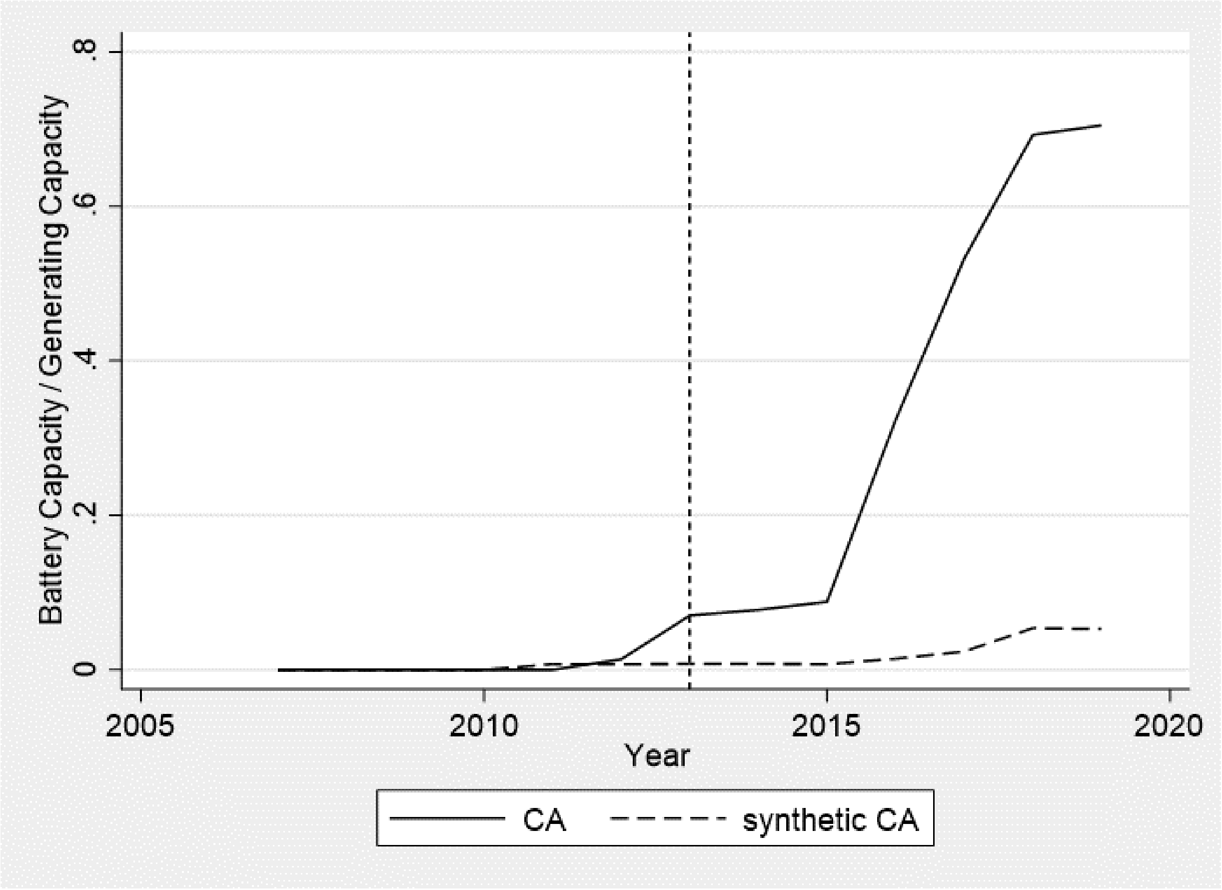
Case #1 California's Energy Storage Mandate



Source: CEC, 2023

- In 2013, California issued a mandate to the state's investor-owned utilities to procure 1.3 GW of energy storage
- Since then, battery storage capacity has increased 20x, and the state currently has ~5 GW of battery storage capacity
- How much did the mandate influence deployment? How much would have been installed without it?
- What was the broader impact of the policy?

Methods and Results



- We developed several difference in difference models to compare California to similar states without battery mandate
  - Models are weighted to account for conditions like political factors, renewable penetration, cooling degree days, and commercial/industrial loads
- Synthetic controls draw from multiple states to closely match California, before the mandate takes effect
- We find that California deployed roughly 500 MW more than they would have without the mandate

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Learning Rate Analysis

POTENTIAL LEARNING ATTRIBUTABLE TO MANDATE (CELL ONLY)

Learning rate	14%	20%	30%
Total cost reduction from doubling of market ($/kWh)	$66	$94	$141
Cost reduction attributable to mandate ($/kWh)	$0.76	$1.09	$1.63

POTENTIAL LEARNING ATTRIBUTABLE TO MANDATE (STORAGE BLOCK)

Learning rate	10%	12.5%	15%
Total cost reduction from doubling of market ($/kWh)	$68	$86	$103
Cost reduction attributable to mandate ($/kWh)	$0.79	$0.99	$1.19

- Most, if not all technologies follow a learning curve, where costs decline by a certain percentage for each doubling of shipments
  - For Li-ion batteries estimates of the learning rate range from 10-30%
- We find that the demand induced by the CA mandate contributed to just over 1% of deployment needed for capacity to double in 2013
- This accounts for a roughly $1/kWh decline in battery costs
- Does not include soft costs, which PNNL is working to benchmark in FY24

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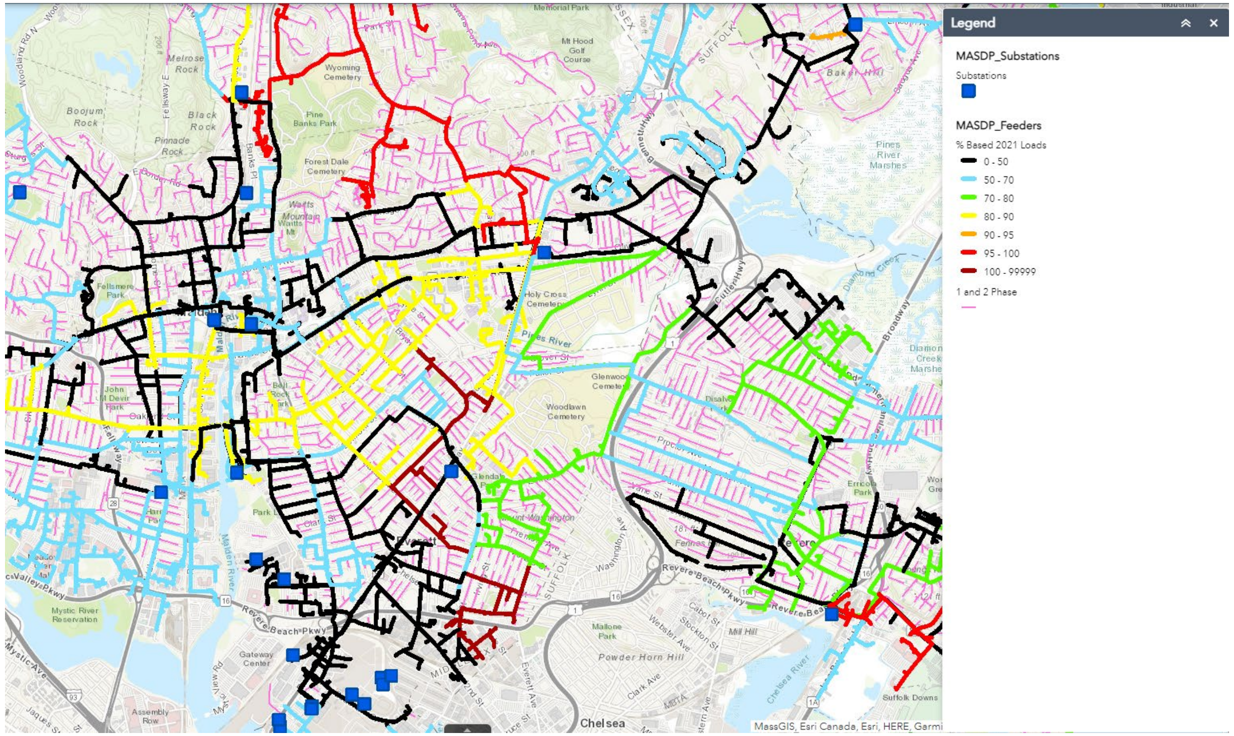
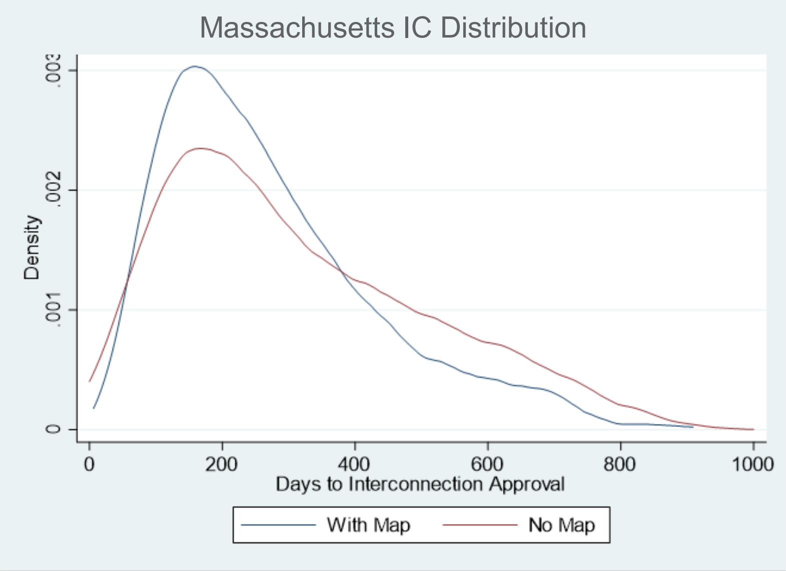
Case #2 State Interconnection Policy

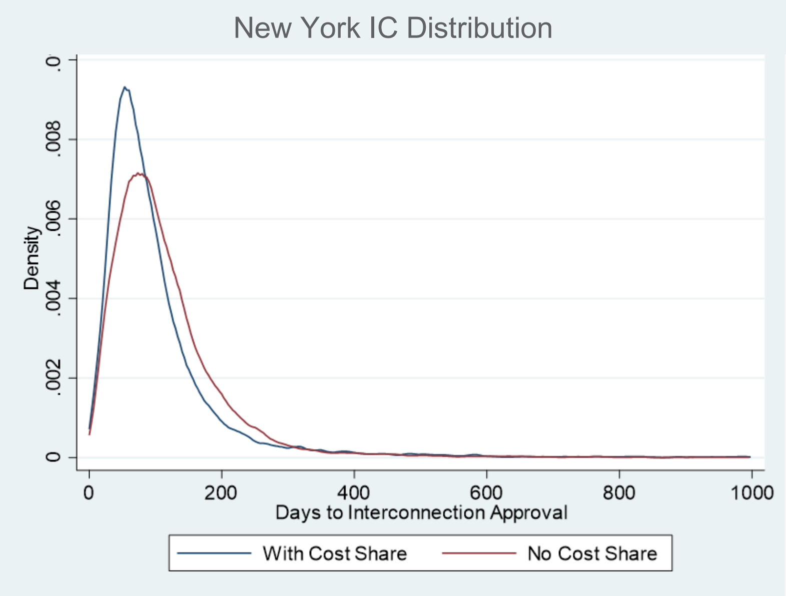


Source: [National Grid, 2023]()

- Long interconnection queues have become a national issue as new generators seek to connect to the grid
- Many states have implemented new policies to reduce wait times for small systems that could be replicated elsewhere
  - States across the country are experimenting, allowing us to choose polices that are interesting and potentially impactful
- We examine policies to see what the impact on queue times were for energy storage and other technologies, each designed to address a clear market failure that leads to withdrawals and rejections
  - Massachusetts publishes maps of feeder hosting capacity to indicate where systems can be built without upgrades, eliminating an information asymmetry
  - New York instituted a cost sharing policy allowing customers to be reimbursed if other projects benefit from feeder upgrades, potentially resolving a free rider issue
- Full results are published in a [PNNL technical report]()

Methods and Results





- For both states, we develop two pools of projects
  - One pool that encompasses projects that filed for IC between the start of the policy to present (treated group)
  - Another pool that encompasses installed immediately before the policy took effect (control group)
- We develop several regression models (OLS, log-linear, negative binomial) to measure how long typical projects took to reach IC during these periods
- Massachusetts saw queue times reduce by 107 days after providing information on feeder congestion
  - While there was limited impact to the mode distribution, fewer projects saw very long wait times (400+ days)
- Impact in New York was much more muted
  - Limitations of the cost sharing policy may not have been enough to overcome the free rider issue
- In both states projects that included storage took longer to interconnect than other project types
  - Shows that there is opportunity to leverage storage to meet interconnection goals

Conclusions

- Econometric techniques can help analysts understand the real-world impacts of various energy policies
  - We look at two examples with potential impacts for energy storage – the role of mandates in California, and impacts to interconnection queue reform in New York and Massachusetts
- Mandates were successful in inducing 500 MW of battery deployment between 2013 and 2019
  - This was sufficient demand to reduce global dell prices by about $1/kWh
- State interconnection reforms show mixed effects
  - Providing transparency on hosting capacity appears to have substantial impacts on queue time
  - Regulators have struggled to solve cost sharing and free rider issues
  - In both cases, there is evidence that energy storage could be leveraged to improve queue outcomes

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Thank you

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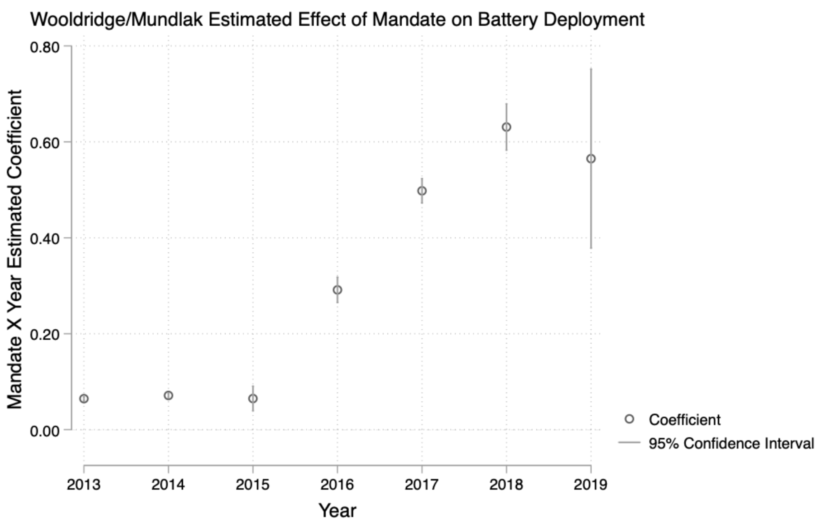
Appendix – California Difference in Differences Results



	(1) Baseline DiD	(2) Wooldridge/Mundlak
Storage Mandate	0.312***	0.312***
	(0.0216)	(0.0215)
Constant	0.000	-0.0205*
	(0.0115)	(0.0116)
Observations	598	598
R-squared	0.256	0.256

Notes: This table reports difference-in-differences results for the effect of the California storage mandate on total battery deployment. The dependent variable is a total battery capacity/net summer capacity as a percent in each state for each year. The first column reports the difference-in-differences results with state and year fixed effects. The second column reports the average of the time-varying difference-in-differences results from the two-way Mundlak estimator which includes time dummies for heterogeneous trends. Errors are clustered at the state level. *** p<0.01, ** p<0.05, * p<0.1.

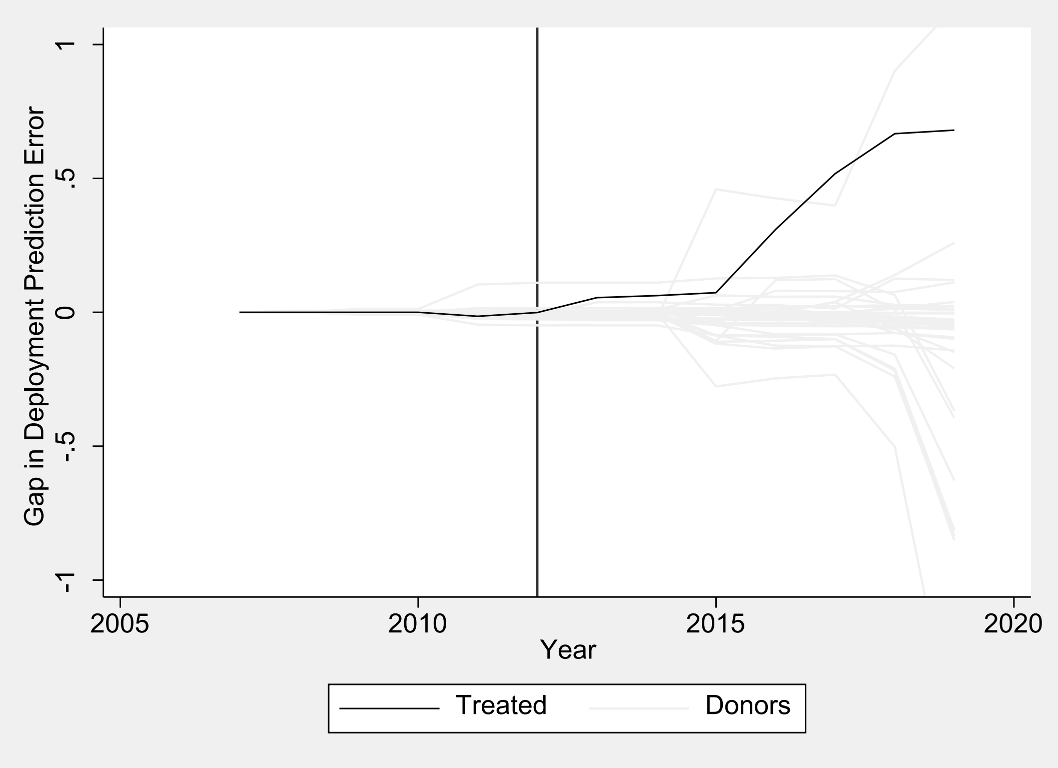
VARIABLES	(1) Wooldridge/Mundlak	(2) Wooldridge/Mundlak with RPS	(3) Wooldridge/Mundlak with NG Prices	(4) Wooldridge/Mundlak with EV Count
Storage Mandate 2013	0.0646***	0.109*	0.125**	0.0490
	(0.0020)	(0.0545)	(0.0546)	(0.0638)
Storage Mandate 2014	0.0713***	0.116**	0.140***	0.152***
	(0.00205)	(0.0488)	(0.0512)	(0.0517)
Storage Mandate 2015	0.0649***	0.201**	0.215***	0.201**
	(0.0127)	(0.0771)	(0.0786)	(0.0887)
Storage Mandate 2016	0.291***	0.476***	0.504***	0.488***
	(0.0131)	(0.105)	(0.105)	(0.0980)
Storage Mandate 2017	0.498***	0.702***	0.735***	0.607***
	(0.0126)	(0.119)	(0.121)	(0.0722)
Storage Mandate 2018	0.631***	0.934***	0.969***	
	(0.0239)	(0.129)	(0.129)	
Storage Mandate 2019	0.565***	1.066***	1.099***	
	(0.0925)	(0.179)	(0.174)	
Constant	-0.0205*	-0.000746	-0.0559**	-0.0213**
	(0.0117)	(0.00382)	(0.0219)	(0.00850)
Observations	598	598	598	434
R-squared	0.275	0.857	0.859	0.888
ATT	0.312***	0.5149***	0.5410***	0.2996***
	(0.0217)	(0.0858)	(0.0858)	(0.0548)

Notes: This table reports difference-in-differences results for the effect of the California storage mandate on total battery deployment. The dependent variable is each state's cumulative total battery capacity/net summer capacity. The first column reports the annual difference-in-differences results from the two-way Mundlak estimator which includes time dummies for heterogeneous trends. The second column adds time and cross-sectional averages of RPS policy variables (RPS step and terminus, solar carveout step and terminus). The third column time and cross-sectional averages of natural gas prices. The fourth column adds time and cross-sectional averages of state-level electric vehicle counts. Errors are clustered at the state level.
*** p<0.01, ** p<0.05, * p<0.1.

Appendix California Synthetic Control Results

	California	
Variables	Real	Synthetic
% Of Legislature that is Democratic	0.63	0.62
GSP Per Capita ($)	56,274.38	51,503.32
Manufacturing GSP Per Capita ($)	6,640.16	4,503.77
Mining GSP Per Capita ($)	48.30	524.95
Share of Revenue from Industrial Customers	0.15	0.19
Share of Revenue from Commercial Customers	0.47	0.40
Renewables Share of Generation Capacity	0.30	0.19
Wind Share of Generating Capacity	0.05	0.07
Solar Share of Generating Capacity	0.01	0.00
Natural Gas Share of Generating Capacity	0.62	0.36
Annual per capita Renewable Generation	3,049.85	4,736.93
Renewables Portfolio Standard Step	0.13	0.06
Cooling Degree Days	895	683.48

State	Weight
NM	0.46
CO	0.269
CT	0.152
WA	0.12



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Appendix – Massachusetts Results

	1		2		3		5		6	
	Ordinary Least Squares						Log Linear Transformation		Negative Binomial Regression	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
After Map available	-107***	10.3	-95.2***	10	-96.6***	10	-.354***	0.0375	-.34***	0.0355
Expedited	-146***	13.3	-108***	11	-110***	9.83	-.392***	0.0381		
Required Study	40.1***	14.7							-.0948***	0.035
Design Capacity kW	.072**	0.0297	.154***	0.0497	.155***	0.051	.000255**	0.000118	.000242*	0.000123
NEM	-52.4***	10.6	-19.4**	8.98			.0888**	0.0396	0.00777	0.0372
Queue Volume	.00589***	0.000802	.00603***	0.000778	.00607***	0.00078	1.0e-05***	2.30E-06	.000031***	3.10E-06
Queue Count	10.3***	1	10.1***	0.992	10***	0.993	.0224***	0.00323	.0479***	0.00285
Queue Volume * Queue Count	-.000046***	6.40E-06	-.000047***	6.30E-06	-.000046***	6.30E-06	-8.4e-08***	1.50E-08	-2.5e-07***	1.90E-08
IC Plan Modified	79.1***	8.92	85.6***	8.88	78.5***	8.27				
Withdraw Volume count	-10.6***	2.18	-11.1***	2.12	-11.2***	2.12			-.0529***	0.00699
Withdraw Volume Capacity	.0114***	0.00255	.0115***	0.00246	.0115***	0.00246	-.000013***	2.80E-06	.00009***	9.80E-06
Withdraw Volume count * Withdraw Volume Capacity	-.000154***	0.000033	-.000149***	0.000032	-.000148***	0.000032			-1.1e-06***	1.30E-07
Q4	37.5***	10.8	38.4***	10.3	39***	10.4				
Customer delays	1.43***	0.234	1.42***	0.23	1.43***	0.225	.00614***	0.000767	.00315***	0.000604
Sector										
Commercial									0	0
Residential			-75.1***	9.97	-81.1***	9.89	-.312***	0.035	-.323***	0.032
Utility			-228**	89.3	-233**	91.4	-0.331	0.217	-.389**	0.182
Hybrid			-83.1***	26.6					-1.45	0.0382
Has storage			33.8	22.7	-33.1***	12.2			0.234	0.00895
Intercept	-607***	85.8	-556***	86.4	-551***	86.9	4.27***	0.229	.55*	0.302
Inalpha									-1.45	0.0382
Alpha									0.234	0.00895

*** p<0.001, ** p<0.01, * p<0.05

Appendix – Massachusetts Results

	1		2		3		1		2	
	Ordinary Least Squares						Log Linear Transformation		Negative Binomial Regression	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
After cost share	-11.1***	0.965	-11.3***	0.965	-11.9***	0.964	-.148***	0.00737	-.131***	0.0074
NEM	-73.3***	12.8	-73.9***	12.7	-73.1***	12.8	-.207***	0.038	-.396***	0.0438
Value stack	-20.1	17.6	-17.8	17.6	-18.9	17.6	0.096	0.0523	0.0189	0.0482
Study type										
Application review only										
Preliminary review	-20***	1.66	-21.3***	1.68	-21.5***	1.67	-.243***	0.0135	-.192***	0.0134
CESIR	217***	21.7	216***	21.7	216***	21.7	.532***	0.0564	.298***	0.0425
Capacity										
0-25 kW										
26-50kW	142***	10.6	143***	10.5	142***	10.6	.734***	0.0419	.877***	0.0429
51-499kW	297***	14.9	298***	14.9	298***	14.9	1.34***	0.0393	1.33***	0.0382
500-1999kW	581***	33.5	581***	33.5	582***	33.6	1.61***	0.0812	1.58***	0.0588
2000-4999kW	773***	35	774***	35.2	775***	35.1	1.84***	0.0928	1.7***	0.0642
5000kW or above	638***	40.8	646***	40.4	639***	40.8	1.73***	0.144	1.57***	0.0759
Queue count	.0359***	0.00457	.0358***	0.00457	.0353***	0.00456	0.000014	0.000032	.000155***	0.000034
Hybrid	32***	6.94			47.3***	7.14	.435***	0.0438	.483***	0.0405
Has storage			-21.2***	1.5	-24.2***	1.52	-.296***	0.014	-.263***	0.0141
Intercept	140***	14.4	143***	14.4	143***	14.3	4.66***	0.0541	4.93***	0.0595
lnalpha									-.784***	0.00686
alpha									.457***	0.00313

*** p<0.001, ** p<0.01, * p<0.05

Appendix – MA and NY Variable Definitions

Variable	Description
After Map available	Dummy variable indicating whether the interconnection application was submitted before or after hosting capacity maps were available
After cost share	Whether or not application submitted after cost share went into effect
Expedited	Dummy variable indicating whether the interconnection application received expedited status
Required Study	Dummy variable indicating whether the interconnection application required a detailed network study
Design Capacity kW	The proposed capacity of the project
NEM	Dummy variable indicating whether the interconnection application was for a net metered project
Queue Volume	The average volume of projects (in terms of total proposed capacity) in the interconnection queue
Queue Count	The average count of projects (in terms of total number of applications) in the interconnection queue
Queue Volume * Queue Count	Interaction term between queue volume and queue count
IC Plan Modified	Dummy variable indicating whether the interconnection application was modified at any point during the approval process
Withdraw Volume count	The average count of projects (in terms of total number of applications withdrawn) during project's time in the interconnection queue
Withdraw Volume Capacity	The average volume of projects (in terms of total proposed capacity) during project's time in the interconnection queue
Withdraw Volume count * Withdraw Volume Capacity	Interaction term between withdraw volume count and withdraw volume capacity
Q41	Dummy variable indicating whether an application was submitted in October, November, or December of a given year
Preliminary review	Whether or not application had to go through a preliminary review after initial application review
Customer delays	Total count of days in which the application was pending a response from the customer
Sector	Dummy variable indicating the sector (residential, commercial utility) of a proposed project
Value stack	Whether or not system is compensated via value stack methodology
CESIR	Whether or not application had to go through a Coordinated Electric System Interconnection Review (CESIR)
Hybrid	Dummy variable indicating whether the interconnection application was for a hybrid system (e.g. uses two or more energy generating or storage project).
Has storage	Dummy variable indicating whether the interconnection application included an energy storage technology

[1] The fourth quarter of a given year, generally sees a greater number of submissions as developers rush to claim the Investment Tax Credit for a given year