Charged Up: Impacts of Green Energy Transition on Local Labor Markets

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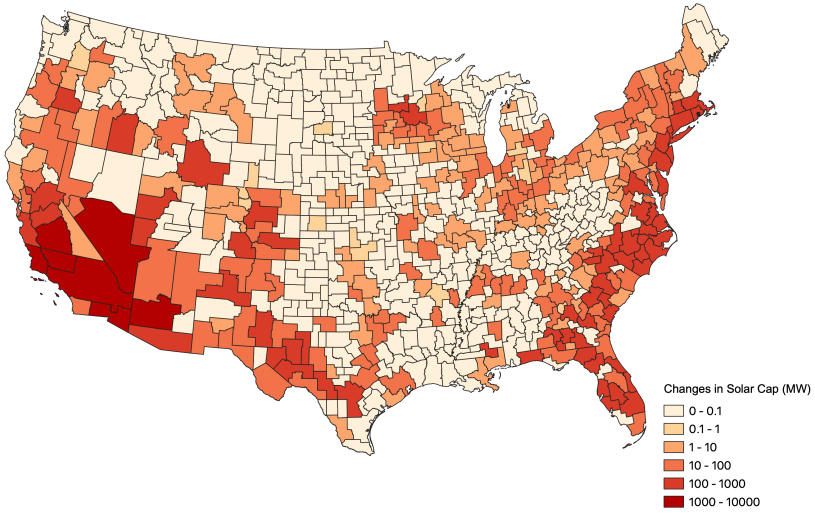
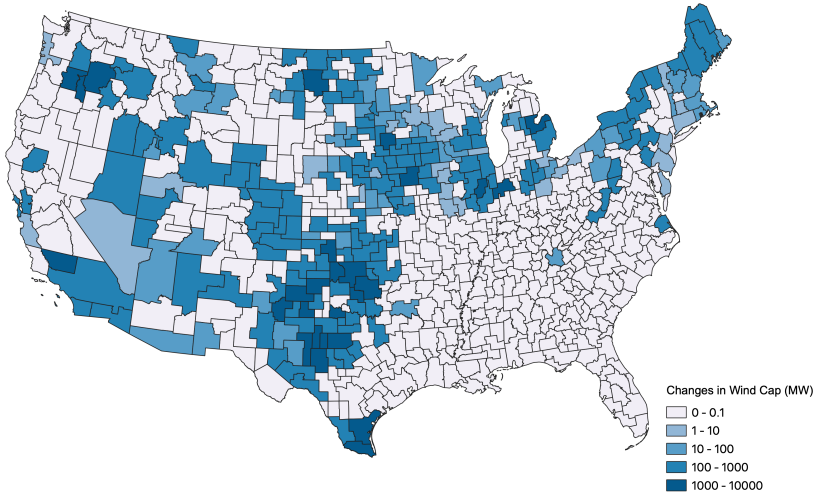
Research area: Energy transition and local labor market

- The shift from fossil fuel to renewable energy will undoubtedly lead to labor market re-organization
- The sectoral shift and geographical redistribution of economic opportunities will have implications on workers' welfare
- How are local workers affected? What might have been the potential explaining factors? What about distributional consequences?
- Does the grow in renewable energy lead to a local agglomeration effect? What are the obstacles that hinders the job transition?

This paper





- We study the effect of utility-scale solar and wind expansion on the US local labor markets from 2005 to 2019
- We study (i) temporal dynamics, (ii) local spillover, (iii) sectoral differences in order to gain some insights on the mechanism
- We conduct a comprehensive distributional analysis across workers

Our focus: Workers in the Local Economy

We look at:

- employment & other extensive margins (e.g., labor participation, population)
- wages & intensive margins (e.g., weeks/hours worked)
- sectoral & other distributional effects (e.g., by demographics), government transfer payments, local business, and other outcomes

Findings in our paper

- We study the effect of solar and wind expansion on the US local labor markets from 2005 to 2019
  - We find solar and wind increase employment in the area, and induce in-migration
  - Solar power also increases wages
- We study (i) temporal dynamics, (ii) local spillover, (iii) sectoral differences in order to gain some insights on the mechanism
  - Initial capacity investment leads to positive gains five years later
  - Limited spatial spillover
  - Growth in manufacturing jobs and number of establishments
- We conduct a comprehensive distributional analysis across workers
  - Positive impact is concentrated among younger, lower-educated, non-Hispanic white workers

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Empirical specification

For a commuting zone (CZ) i in a year t, we estimate:

$$\Delta Y_{it} = \alpha_t + \beta_s \Delta RE_{it}^{solar} + \beta_w \Delta RE_{it}^{wind} + \mathbf{X}'_{it}\delta + \phi_s + \phi_t + \phi_s \cdot t + \varepsilon_{it} \quad (1)$$

- Y – log employment, labor force participation, wage, ...
- RE - log solar and wind capacity
- **X** – controls: log population$_{t-1}$, log coal capacity retirement
- Baseline FD: stacked 1-year first-difference (FD)
- Standard errors clustered at state level

Empirical specification

Potential endogeneity

- **Identification challenge:** shocks in the local labor market may correlate with the propensity of renewable investment in a location
- Need to find an instrument that captures potential benefit of installing renewable energy in a particular CZ
- **Our solutions:** combining cross-sectional renewable potentials with temporal policy shifters
- Renewable potentials are solar irradiance and (cubic) wind speed that are highly correlated with generation capacity
- Temporal shifters: Renewable portfolio standards (RPS) and production tax credits (PTC)

▸ Solar potential ▸ Wind potential

Data sources

- Main specifications:
  - Employment and wage: aggregated from ACS microdata
  - Solar and wind capacity: EIA-860
  - Solar and wind potential: aggregated from grid-level solar GHI and average wind speed^3 from NREL
  - Renewable portfolio standard: the Berkeley Lab + DSIRE
  - Production tax credits: DOE
- Additional results:
  - Occupation code: Occupational Information Network (O*NET) database from US Department of Labor
  - Sectoral business establishment: County Business Patterns (CBP) database from US Census
  - Government transfer receipt payment: Regional Economic Accounts from the US Bureau of Economic Analysis (BEA)

▸ Summary statistics ▸ Cumulative changes in RE

Results

Employment and migration

Dependent variable:	Δ ln employment	Δ ln labor force participation	Δ ln population	Δ ln new-resident population
	(1)	(2)	(3)	(4)
Δ ln (solar capacity)	0.0287****	0.0277****	0.0120**	0.0349****
	(0.0031)	(0.0028)	(0.0049)	(0.0081)
Δ ln (wind capacity)	0.0138**	0.0134**	0.0162*	0.0118
	(0.0066)	(0.0066)	(0.0095)	(0.0128)
$\ln(\text{population})_{t-1}$	X	X		
$\ln(\text{coal capacity retirement})_t$	X	X	X	X
Number of observations	10,094	10,094	10,094	10,094

Notes: Robust standard errors clustered at the state level in parenthesis. *, **, ***, and **** indicate statistical significance at 10, 5, 1, and 0.1 percent levels, respectively.

▸ First stage

- a 10% increase in solar capacity in 2019 (around 12 MW) will lead increase employment by 1,143 (0.3%), population by 511 (0.1%), and new resident population by 224 (0.4%)

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▶ First stage

- a 10% increase in wind capacity in 2019 (around 41 MW) will lead increase employment by 369 (0.1%) and population by 464 (0.2%)

Results

Wages and hours worked

Dependent variable:	Δ ln wage annually	Δ ln wage weekly	Δ ln wage hourly	Δ ln weeks worked per year	Δ ln hours worked per week
	(1)	(2)	(3)	(4)	(5)
Δ ln (solar capacity)	0.0150****	0.0246****	0.0291****	-0.0156****	0.0008*
	(0.0037)	(0.0044)	(0.0065)	(0.0019)	(0.0004)
Δ ln (wind capacity)	-0.0013	-0.0004	-0.0091	0.0012	0.0013
	(0.0051)	(0.0073)	(0.0105)	(0.0030)	(0.0012)
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- a 10% increase in solar capacity in 2019 leads to a $1.9 increase in weekly wage (0.3%) and a $50.6 increase in annual wage (0.2%) (in 2005 USD)

Results

Evaluating temporal effects using LP-DiD

- We estimate the equation below based on our main specification:

$$\Delta Y_{it,t+h} = \gamma_{s,h}\Delta D_{it}^{solar} + \gamma_{w,h}\Delta D_{it}^{wind} + \mathbf{X}'_{it}\delta + \phi_t + \phi_s + \phi_s \cdot t + \varepsilon_{it} \quad (1)$$

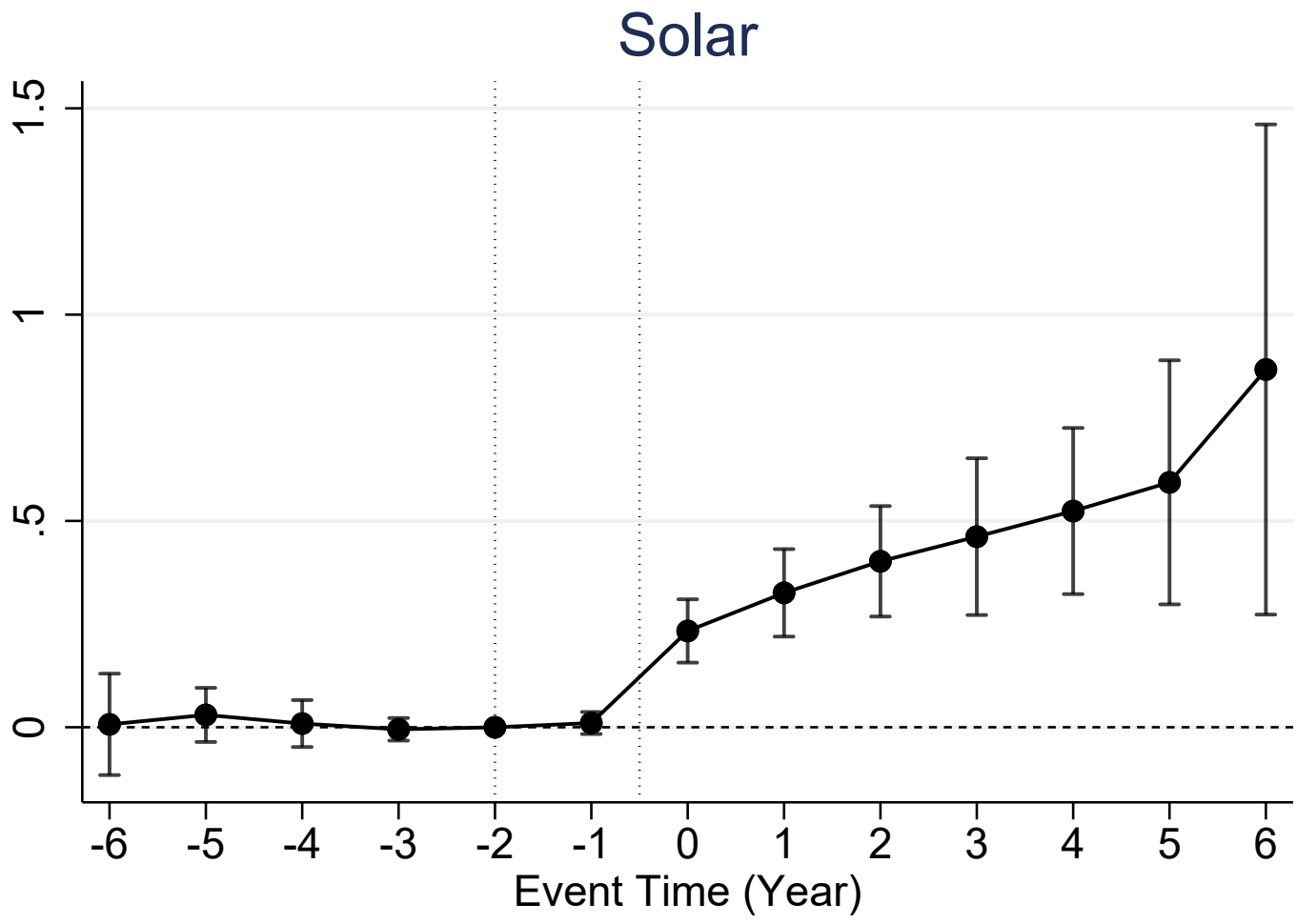
  where $h \in [-6, 6]$ is the event time, i.e., the number of years before or after the year when a CZ experiences its initial expansion in solar or wind energy.

- Following the base specification in Dube et al. (2023):
  - set the variable interest D_{it} being the dummy variable indicates whether a CZ i has ever experienced any wind/solar investment
  - set a clean control condition (separately for each wind and solar)
  - includes the same set of controls, fixed effects, and instruments

- We normalize to two years before the first capacity increase to consider the construction stage as discussed in past studies

Results

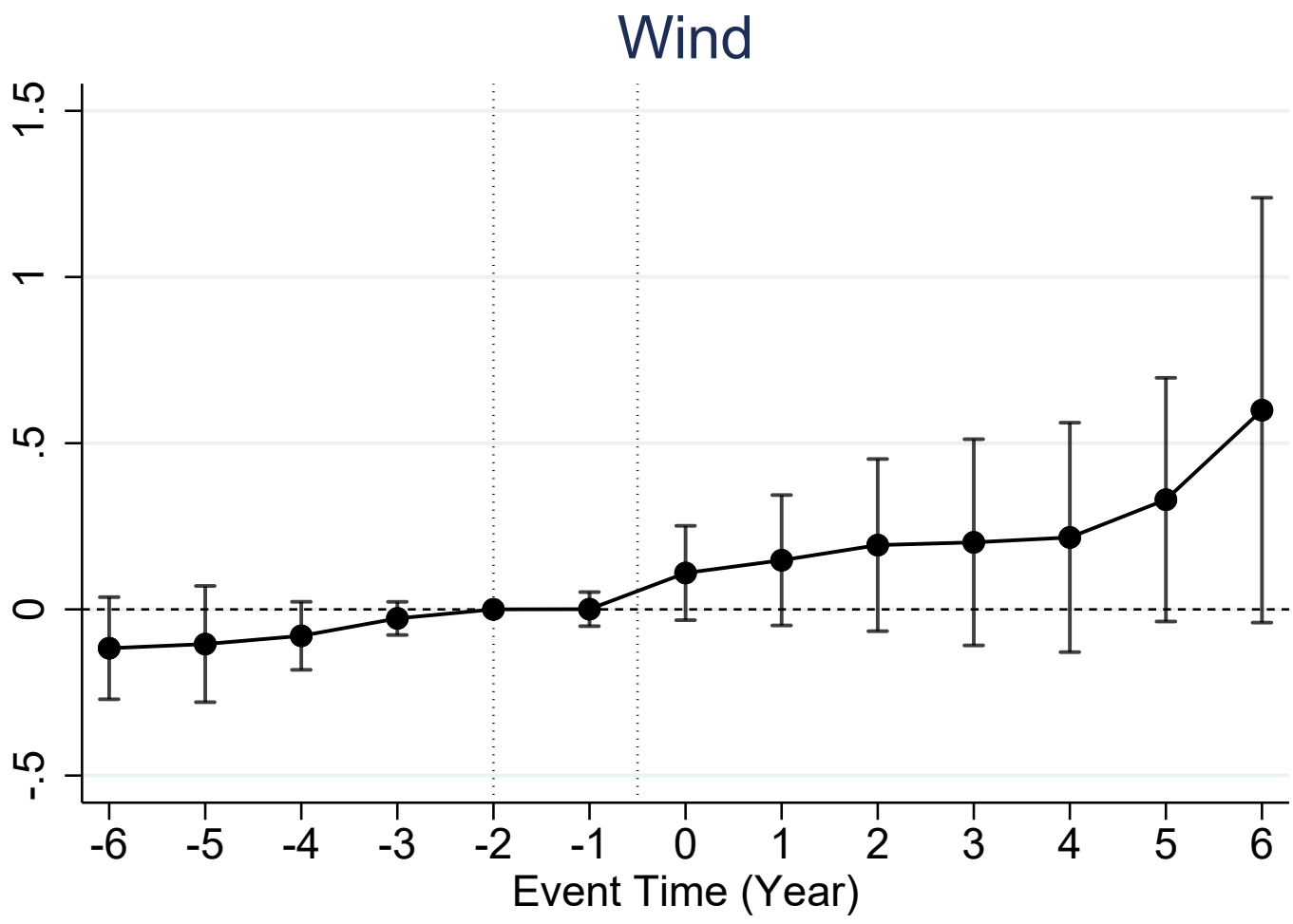
Temporal effects on employment



▸ Wage effects

Results

Temporal effects on employment



▸ Wage effects

Results

Sectoral impacts

Dep. var: Δ ln *employment*

	All	Manufacturing	Service	Other	Public
	(1)	(2)	(3)	(4)	(5)
Δ ln(solar capacity)	0.0287****	0.0745****	0.0228****	0.0210****	-0.0190***
	(0.0031)	(0.0086)	(0.0030)	(0.0040)	(0.0068)
Δ ln(wind capacity)	0.0138**	0.0180	0.0166**	0.0075	-0.0166
	(0.0066)	(0.0150)	(0.0071)	(0.0059)	(0.0151)

	Utility	Construction	Wholesale	Transport
	(4a)	(4b)	(4c)	(4d)
Δ ln(solar capacity)	-0.0081	0.0480****	0.0109***	0.0234***
	(0.0158)	(0.0102)	(0.0036)	(0.0071)
Δ ln(wind capacity)	0.0010	0.0113	0.0010	-0.0119
	(0.0273)	(0.0114)	(0.0079)	(0.0213)

Notes: Robust standard errors clustered at the state level in parenthesis. *, **, ***, and **** indicate statistical significance at 10, 5, 1, and 0.1 percent levels, respectively.

▸ Results by business establishments

Results

Sectoral impacts

Dep. var: Δ ln *employment*

	All (1)	Manufacturing (2)	Service (3)	Other (4)	Public (5)
Δ ln(solar capacity)	0.0287****	0.0745****	0.0228****	0.0210****	-0.0190***
	(0.0031)	(0.0086)	(0.0030)	(0.0040)	(0.0068)
Δ ln(wind capacity)	0.0138**	0.0180	0.0166**	0.0075	-0.0166
	(0.0066)	(0.0150)	(0.0071)	(0.0059)	(0.0151)

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- Employment gain due to solar also happens in other sectors such as manufacturing and service sectors, in addition to construction

Results by business establishments

Distributional effects

Employment effects by age and educational attainment

Dep. var.: Δ ln *employment*	(1)	(2)	(3)	(4)	(5)	(6)
A. Effects by Age						
	All workers	16–35	36–50	51–64		
Δ ln (solar cap.)	0.0287****	0.0377****	0.0358****	0.0061**		
	(0.0031)	(0.0058)	(0.0038)	(0.0026)		
Δ ln (wind cap.)	0.0138**	0.0230**	0.0106	0.0012		
	(0.0066)	(0.0113)	(0.0086)	(0.0062)		
B. Effects by Educational Attainment						
	All workers	Less than high school	High school degree	Some college	College degree	Post-grad degree
Δ ln (solar cap.)	0.0287****	0.1159****	0.0049	0.0179***	0.0064*	0.0184***
	(0.0031)	(0.0149)	(0.0031)	(0.0063)	(0.0036)	(0.0052)
Δ ln (wind cap.)	0.0138**	0.0584*	0.0063	-0.0224**	0.0046	0.0260**
	(0.0066)	(0.0292)	(0.0066)	(0.0104)	(0.0086)	(0.0120)

Notes: Robust standard errors clustered at the state level in parenthesis. *, **, ***, and **** indicate statistical significance at 10, 5, 1, and 0.1 percent levels, respectively.

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Distributional effects

Employment effects by race and gender

Dep. var.: Δ ln *employment*	(1)	(2)	(3)	(4)	(5)	(6)
C. Effects by Race						
	All workers	Non-hisp. white	Hispanic white	Black	Asian	
Δ ln (solar cap.)	0.0287****	0.0164****	-0.0180	-0.0408**	0.0121	
	(0.0031)	(0.0035)	(0.0150)	(0.0190)	(0.0112)	
Δ ln (wind cap.)	0.0138**	0.0222**	-0.0224	-0.0249	-0.0008	
	(0.0066)	(0.0095)	(0.0331)	(0.0369)	(0.0206)	
D. Effects by Gender						
	All workers	Male	Female			
Δ ln (solar cap.)	0.0287****	0.0318****	0.0249****			
	(0.0031)	(0.0032)	(0.0029)			
Δ ln (wind cap.)	0.0138**	0.0157**	0.0111*			
	(0.0066)	(0.0073)	(0.0061)			

Notes: Robust standard errors clustered at the state level in parenthesis. *, **, ***, and **** indicate statistical significance at 10, 5, 1, and 0.1 percent levels, respectively.

▸ Wage effects ▸ Effects by gender and educational attainment

Distributional effects

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Additional results and robustness

- Heterogeneity by green occupations: solar leads to increase in green jobs while wind leads to an increase of brown jobs Details
- We find a reduction in government transfers such as income benefits and food stamps Details
- Robustness:
  - Similar but smaller effect from solar and wind power generation Details
  - Robust to including coal retirement as an additional IV shifter Details
  - Robust to Conley spacial SE and HAC SE
  - Similar results for longer differences Details

Discussions

- So far, we find that an increase in renewable energy in the commuting zone leads to
  - higher employment and wage
  - increase in employment in multiple sectors
  - increase in number of manufacturing establishments
  - lower benefit transfer payments to individuals
- Suggestive evidence that the local economy grows as a result of the green investment
- Our results also suggest there is a multiplier and agglomeration effect from renewable energy installation
  - Similar to earlier evidence found in oil and gas markets in the US (Feyrer et al., 2017; Allcott and Keniston, 2018)

Summary and future directions

- We study the impact of renewable energy expansion in the US on local labor markets
- We find positive effects in employment and wage evidence of growing regional economies (e.g., employment in mfg., business establishment, welfare transfer, etc.) and the effects are not short-lived
- Gains in employment and wages are concentrated in the relatively young, less-educated/lower-skilled, and white workers
- Future directions:
  - How large is the local agglomeration effect, relative to the fossil fuel retirements?
  - Can governments design any place-based policies to improve equity and efficiency?
  - Do these positive effects lead to a change in preference or attitude towards renewable energy?

Allcott, H. and Keniston, D. (2018). Dutch Disease or Agglomeration? The Local Economic Effects of Natural Resource Booms in Modern America. *The Review of Economic Studies*, 85(2):695–731.

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Feyrer, J., Mansur, E., and Sacerdote, B. (2017). Geographic dispersion of economic shocks: Evidence from the fracking revolution. *American Economic Review*, 107(4):1313–1334.

Popp, D., Vona, F., Marin, G., and Chen, Z. (2021). The employment impact of green fiscal push: Evidence from the American Recovery Act. *Brookings Papers on Economic Activity*, Fall 2021:1–49.

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Solar potential by CZ

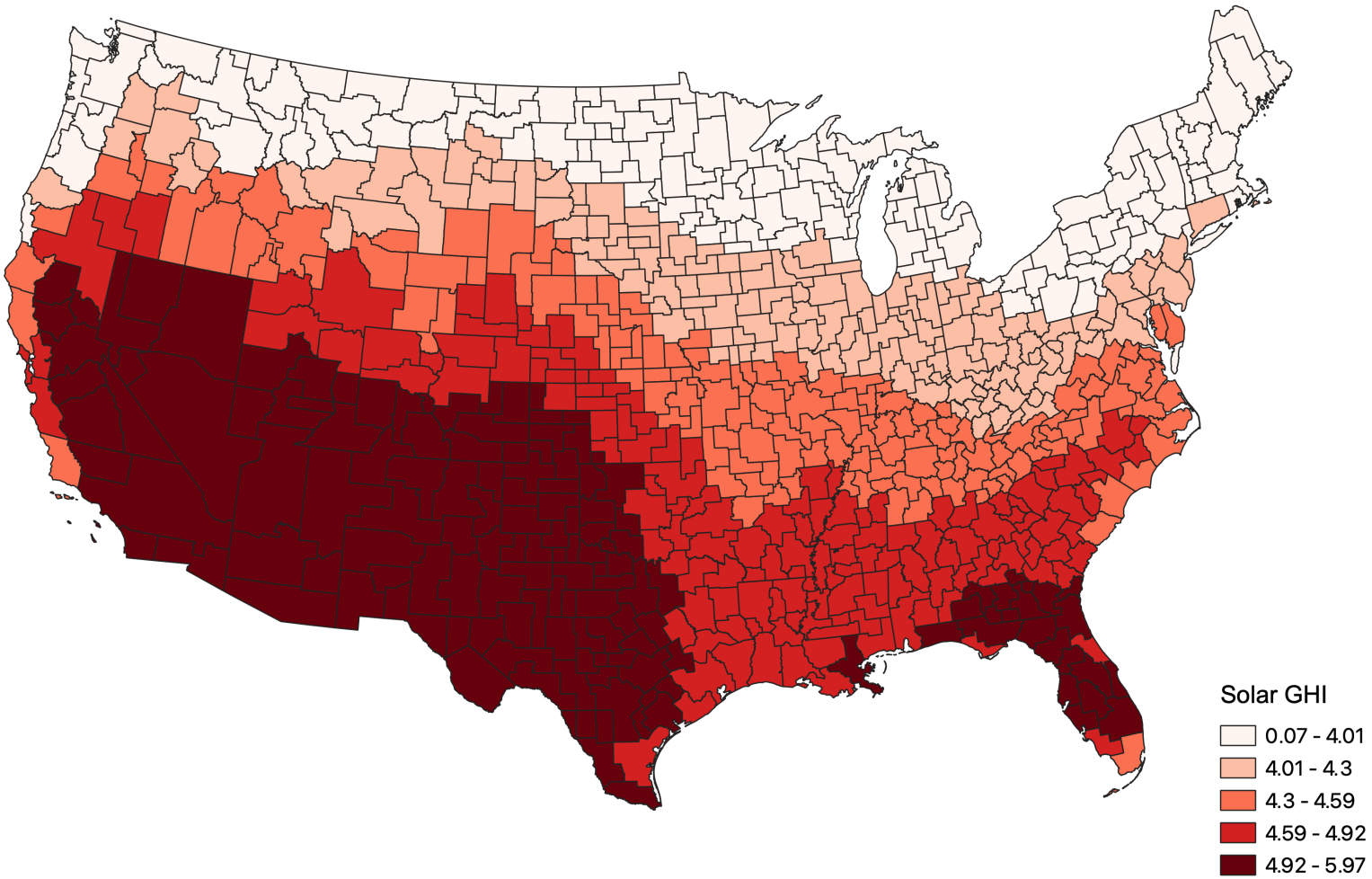

Figure: Solar Global Horizontal Irradiance (GHI)

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Wind potential by CZ

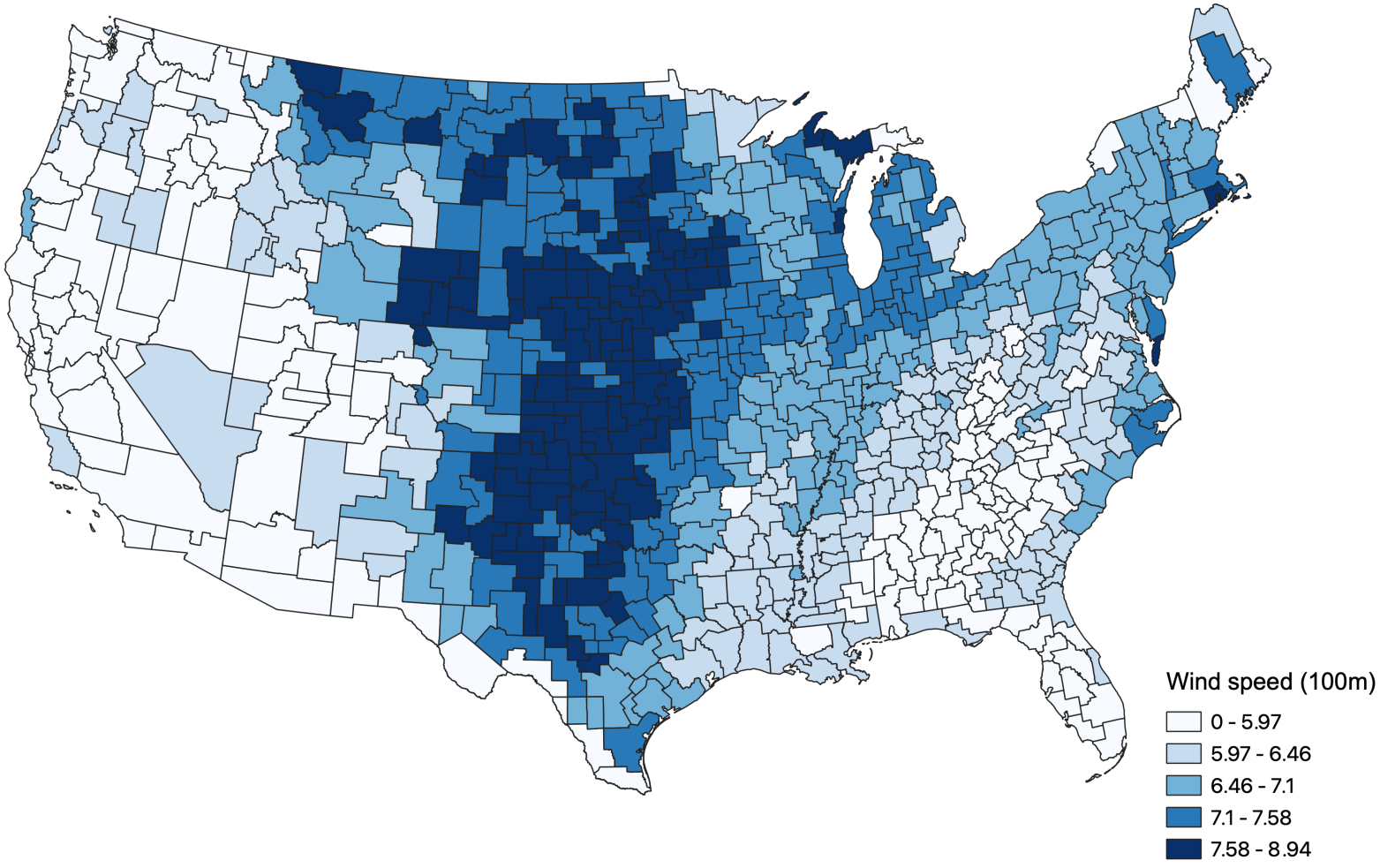

Figure: 120-meter Wind Speed

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Summary statistics

Annual Changes in Key Variables

Variable name:	Mean	St. Dev.	*Variable name:*	Mean	St. Dev.
A.1 Outcome variables			A.2 Variables of interest		
$\Delta \ln$(employment)	0.002	0.044	$\Delta \ln$(solar capacity)	0.092	0.435
$\Delta \ln$(labor force part.)	0.001	0.040	$\Delta \ln$(wind capacity)	0.099	0.609
$\Delta \ln$(population)	-0.002	0.037	$\Delta \ln$(solar net gen.)	0.101	0.586
$\Delta \ln$(annual wage)	0.009	0.058	$\Delta \ln$(wind net gen.)	0.120	0.690
$\Delta \ln$(weekly wage)	0.008	1.403			
$\Delta \ln$(hourly wage)	0.011	1.378			
$\Delta \ln$(weeks worked/year)	-0.001	0.019			
$\Delta \ln$(hours worked/week)	0.004	1.220			
Number of observations					10,094

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Summary statistics

Cumulative Changes in Renewable Energy in a CZ

Variable name:	Mean	St. Dev.	*Variable name:*	Mean	St. Dev.
B.1 Solar			B.2 Wind		
Capacity (MW) in 2005	0.6	14.9	Capacity (MW) in 2005	12.0	61.9
Capacity (MW) in 2019	51.8	253.7	Capacity (MW) in 2019	144.0	375.0
$\Delta \ln(\text{capacity})_{2019-2005}$	1.29	1.93	$\Delta \ln(\text{capacity})_{2019-2005}$	1.39	2.31
Net gen. (GWh) in 2005	0.8	19.9	Net gen. (GWh) in 2005	24.5	136.2
Net gen. (GWh) in 2019	99.3	561.4	Net gen. (GWh) in 2019	409.1	1,053.7
$\Delta \ln(\text{net gen})_{2019-2005}$	1.42	2.15	$\Delta \ln(\text{net gen})_{2019-2005}$	1.68	2.74

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First Stage

Dependent variable:	Δ ln (solar capacity)	Δ ln (wind capacity)
	(1)	(2)
State-level RPS Obligation (TWh)	0.0712**	0.0230
$\times$ CZ Area $\times$ Solar GHI	(0.0268)	(0.0270)
State-level RPS Obligation (TWh)	-0.0022****	-0.0005
$\times$ CZ Area $\times$ 120-meter wind speed^3	(0.0005)	(0.0007)
PTC (Dollar-per-MWh)	-0.0460	-0.1894***
$\times$ CZ Area $\times$ Solar GHI	(0.0593)	(0.0546)
PTC (Dollar-per-MWh)	0.0008	0.0045**
$\times$ CZ Area $\times$ 120-meter wind speed^3	(0.0008)	(0.0012)
Number of observation	10,094	10,094
R-squared	0.13	0.08
Joint-sig. Wald-stat (IVs)	77.5	12.0
Joint-sig. Wald-stat p-value (IVs)	0.000	0.000

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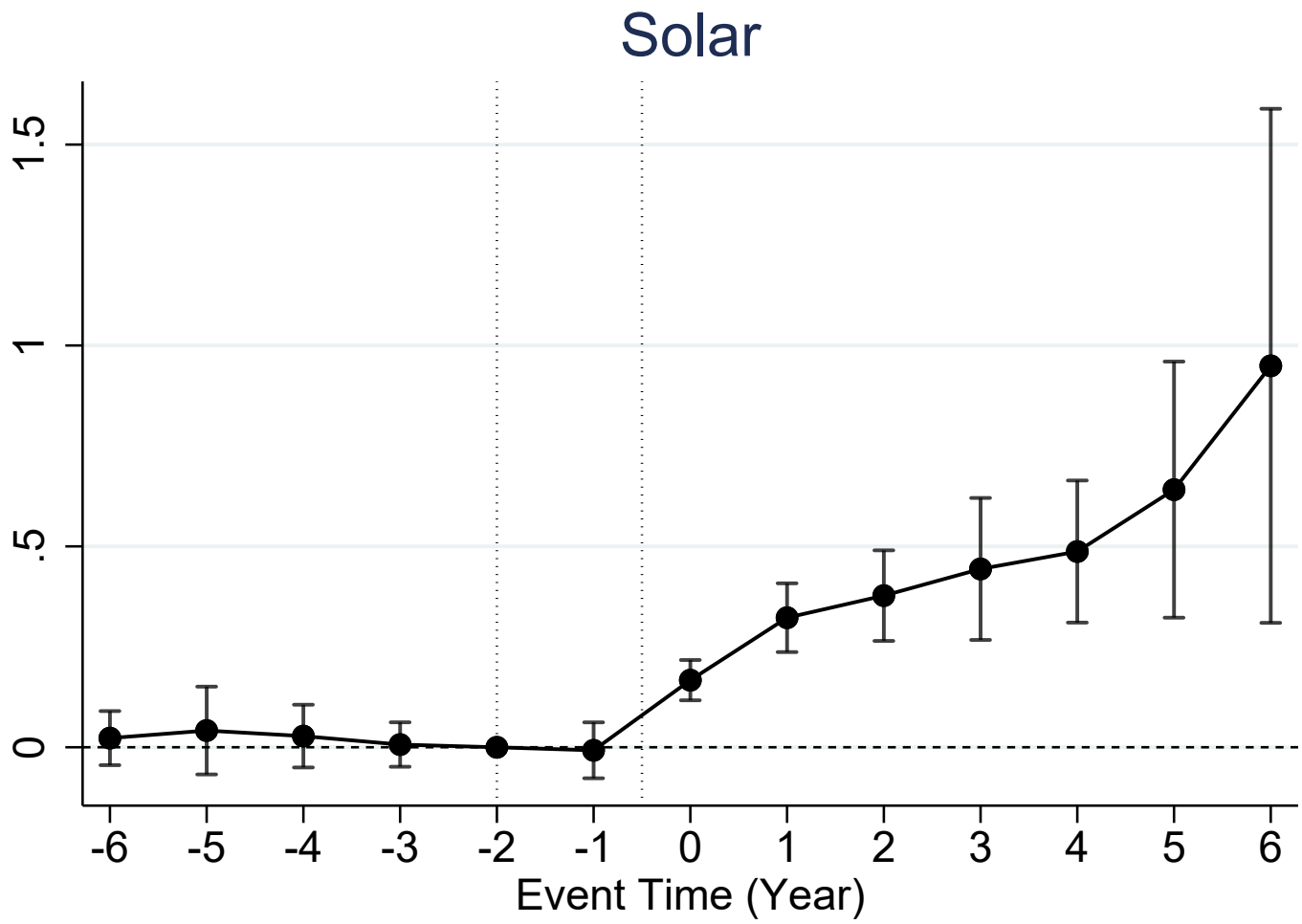
Results

Temporal effects on employment



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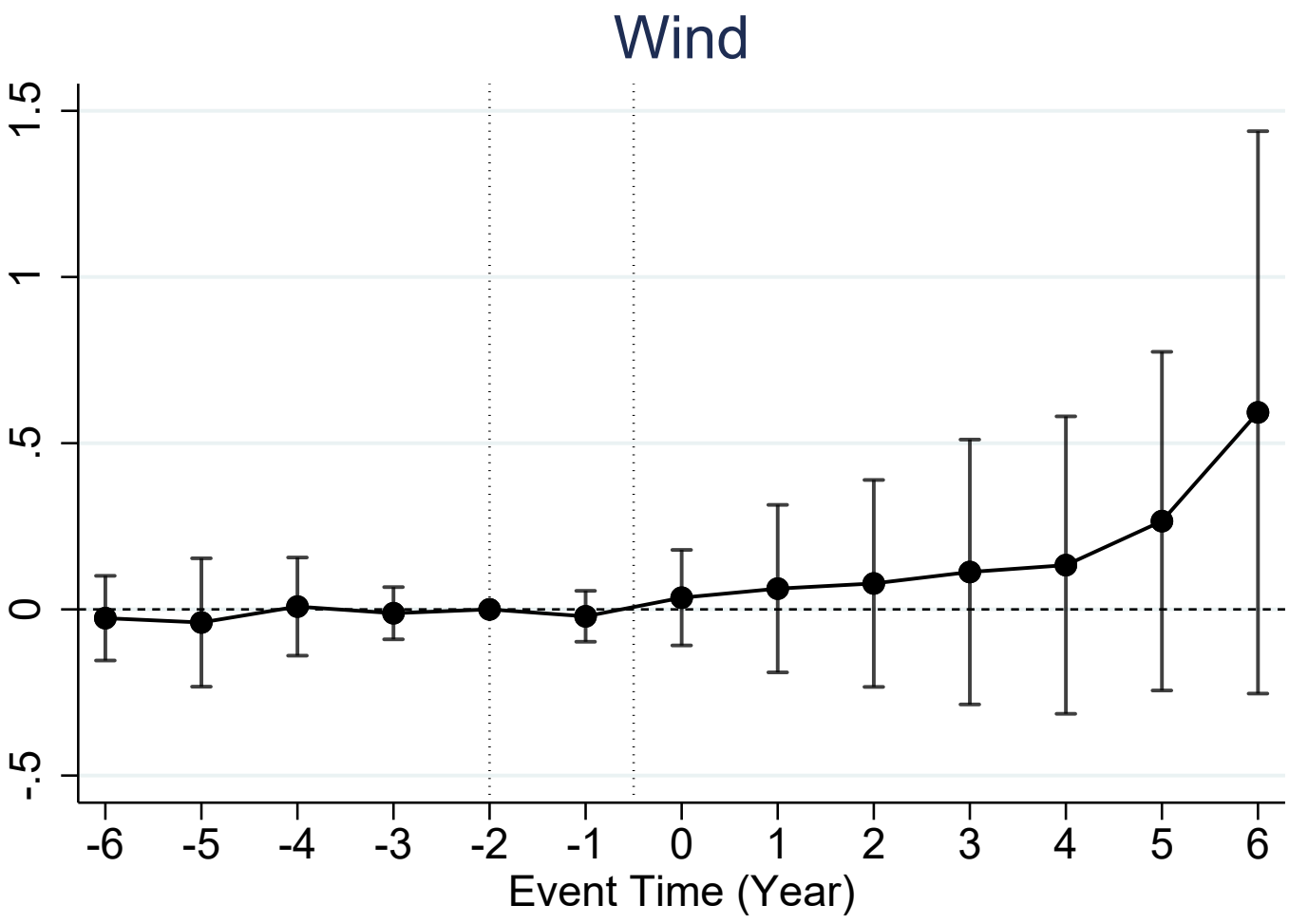
Results

Temporal effects on employment



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Results

Sectoral impacts

Dep. var: $\Delta \ln$ *business establishments*

	All (1)	Manufacturing (2)	Service (3)	Other (4)
$\Delta \ln$(solar capacity)	0.0025	0.0372****	-0.0037	-0.0016
	(0.0020)	(0.0067)	(0.0028)	(0.0024)
$\Delta \ln$(wind capacity)	0.0076*	0.0166	0.0058	0.0051
	(0.0040)	(0.0133)	(0.0041)	(0.0042)
	Utility (4a)	Construction (4b)	Wholesale (4c)	Transport (4d)
$\Delta \ln$(solar capacity)	0.0971****	0.0035	-0.0103****	0.0108
	(0.0193)	(0.0051)	(0.0024)	(0.0101)
$\Delta \ln$(wind capacity)	0.0223	0.0058	0.0041	-0.0005
	(0.0219)	(0.0058)	(0.0047)	(0.0114)

Notes: Robust standard errors clustered at the state level in parenthesis. *, **, ***, and **** indicate statistical significance at 10, 5, 1, and 0.1 percent levels, respectively.

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Results

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- We also observe a growth in the number of manufacturing establishments

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Distributional effects

Wage effects by age and educational attainment

Dep. var.: Δ ln *(weekly wage)*	(1)	(2)	(3)	(4)	(5)	(6)
A. Effects by Age						
	All workers	16–35	36–50	51–64		
Δ ln(solar cap.)	0.0246****	0.0407****	0.0216****	0.0197***		
	(0.0044)	(0.0060)	(0.0036)	(0.0057)		
Δ ln(wind cap.)	-0.0004	0.0019	0.0032	-0.0007		
	(0.0073)	(0.0121)	(0.0084)	(0.0115)		
B. Effects by Educational Attainment						
	All workers	Less than high school	High school degree	Some college	College degree	Post-grad degree
Δ ln(solar cap.)	0.0246****	0.0722****	0.0119*	0.0260****	0.0300****	0.0292****
	(0.0044)	(0.0119)	(0.0062)	(0.0066)	(0.0075)	(0.0059)
Δ ln(wind cap.)	-0.0004	0.0300	0.0034	-0.0043	-0.0018	0.0034
	(0.0073)	(0.0361)	(0.0093)	(0.0097)	(0.0132)	(0.0098)

Notes: Robust standard errors clustered at the state level in parenthesis. *, **, ***, and **** indicate statistical significance at 10, 5, 1, and 0.1 percent levels, respectively.

Distributional effects

Wage effects by race and gender

Dep. var.: Δ ln *(weekly wage)*	(1)	(2)	(3)	(4)	(5)	(6)
C. Effects by Race						
	All workers	Non-hisp. white	Hispanic white	Black	Asian	
Δ ln (solar cap.)	0.0246****	0.0196****	0.0420****	-0.0019	0.0244*	
	(0.0044)	(0.0038)	(0.0071)	(0.0116)	(0.0135)	
Δ ln (wind cap.)	-0.0004	-0.0020	-0.0294*	0.0178	0.0319	
	(0.0073)	(0.0066)	(0.0155)	(0.0162)	(0.0254)	
D. Effects by Gender						
	All workers	Male	Female			
Δ ln (solar cap.)	0.0246****	0.0304****	0.0159****			
	(0.0044)	(0.0055)	(0.0033)			
Δ ln (wind cap.)	-0.0004	-0.0059	0.0069			
	(0.0073)	(0.0096)	(0.0054)			

Notes: Robust standard errors clustered at the state level in parenthesis. *, **, ***, and **** indicate statistical significance at 10, 5, 1, and 0.1 percent levels, respectively.

▸ Effects by gender and educational attainment ▸ Back

Distributional effects

Employment effects by gender and educational attainment

	(1)	(2)	(3)	(4)	(5)	(6)
A.1 For male	All male workers	Less than high school	High school degree	Some college	College degree	Post-grad degree
$\Delta \ln$(solar cap.)	0.0318****	0.1130****	0.0101***	0.0078	0.0139****	0.0330***
	(0.0032)	(0.0167)	(0.0029)	(0.0083)	(0.0038)	(0.0092)
$\Delta \ln$(wind cap.)	0.0157**	0.0585**	0.0072	-0.0301**	0.0076	0.0368**
	(0.0073)	(0.0273)	(0.0063)	(0.0138)	(0.0113)	(0.0162)
A.2 For female	All female workers	Less than high school	High school degree	Some college	College degree	Post-grad degree
$\Delta \ln$(solar cap.)	0.0249****	0.1181****	-0.0012	0.0278****	-0.0009	0.0116**
	(0.0029)	(0.0122)	(0.0037)	(0.0064)	(0.0044)	(0.0054)
$\Delta \ln$(wind cap.)	0.0111*	0.0574	0.0051	-0.0143	0.0005	0.0180
	(0.0061)	(0.0328)	(0.0085)	(0.0119)	(0.0088)	(0.0137)

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Distributional effects

Wage effects by gender and educational attainment

	(1)	(2)	(3)	(4)	(5)	(6)
B.1 For male	All male workers	Less than high school	High school degree	Some college	College degree	Post-grad degree
$\Delta \ln$(solar cap.)	0.0304****	0.0652****	0.0198***	0.0477****	0.0344****	0.0503****
	(0.0055)	(0.0099)	(0.0065)	(0.0060)	(0.0090)	(0.0078)
$\Delta \ln$(wind cap.)	-0.0059	0.0234	0.0043	-0.0076	-0.0143	0.0034
	(0.0096)	(0.0351)	(0.0118)	(0.0124)	(0.0174)	(0.0123)
B.2 For female	All female workers	Less than high school	High school degree	Some college	College degree	Post-grad degree
$\Delta \ln$(solar cap.)	0.0159****	0.0911****	-0.0020	0.0021	0.0186***	0.0066
	(0.0033)	(0.0174)	(0.0059)	(0.0086)	(0.0069)	(0.0069)
$\Delta \ln$(wind cap.)	0.0069	0.0453	0.0020	0.0066	0.0119	0.0081
	(0.0054)	(0.0432)	(0.0067)	(0.0104)	(0.0105)	(0.0115)

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Distributional effects

Measuring occupation greenness

- Green jobs have been an interest of the US environmental and energy policy designs
  - Previous studies have documented growth in green jobs in response to stricter environmental policies and increased government investment in the green economy (e.g., Vona et al., 2018; Popp et al., 2021)
- We first identify "green tasks" for each occupation based on the textual description of each task provided by the O*NET database and define the "greenness" of an occupation based on the fraction of green tasks within that occupation (Vona et al., 2018; Vona, 2021)
- We then compute the minimum greenness of all 8-digit occupations within an ACS 6-digit occupation to link the occupation greenness to the ACS microdata
  - Caveat: underestimate the number of green jobs

Distributional effects

Employment and wage effects by occupation greenness

	All workers	*Least green:* If minimum occupation greenness $= 0$	If minimum occupation greenness $\in (0,\ 0.1]$	*The greenest:* If minimum occupation greenness > 0.1
	(1)	(2)	(3)	(4)
A. Dependent variable: Δ ln *employment*				
Δ ln (solar capacity)	0.0287****	0.0263****	0.1246****	0.0333***
	(0.0031)	(0.0031)	(0.0097)	(0.0073)
Δ ln (wind capacity)	0.0138**	0.0154***	0.0249	-0.0109
	(0.0066)	(0.0066)	(0.0269)	(0.0103)
B. Dependent variable: Δ ln *weekly wage*				
Δ ln (solar capacity)	0.0246****	0.0256****	-0.0133	0.0153
	(0.0044)	(0.0039)	(0.0120)	(0.0164)
Δ ln (wind capacity)	-0.0004	0.0026	0.0101	-0.0179
	(0.0073)	(0.0074)	(0.0158)	(0.0221)
Share of workers		93.2%	1.6%	5.1%

Notes: Robust standard errors clustered at the state level in parenthesis. *, **, ***, and **** indicate statistical significance at 10, 5, 1, and 0.1 percent levels.

Distributional effects

Employment effects by sector and occupation greenness

Dependent variable: $\Delta \ln$ *employment*

	Manufacturing sector			Other sectors (excl. service and gov't.)		
	All occp.:	*Other occp.:* min *green* $= 0$	*Green occp.:* min *green* > 0	*All occp.:*	*Other occp.:* min *green* $= 0$	*Green occp.:* min *green* > 0
	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
$\Delta \ln$(solar cap.)	0.0745****	0.0676****	0.1177****	0.0210****	0.0201****	0.0295***
	(0.0086)	(0.0081)	(0.0198)	(0.0040)	(0.0040)	(0.0089)
$\Delta \ln$(wind cap.)	0.0180	0.0162	-0.0007	0.0075	0.0107*	-0.0136
	(0.0150)	(0.0136)	(0.0297)	(0.0059)	(0.0061)	(0.0106)
Share of workers in a sector		87.6%	12.4%		89.4%	10.6%

Notes: Robust standard errors clustered at the state level in parenthesis. *, **, ***, and **** indicate statistical significance at 10, 5, 1, and 0.1 percent levels, respectively.

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Additional results

Government transfers

Dependent variable: $\Delta \ln$ *Government transfer per capita*

	1. Total	*2. Income maintenance benefits*			
	Total transfer (1)	Income benefits (2)	SSI (2a)	SNAP (2b)	EITC (2c)
$\Delta \ln$(solar cap.)	-0.0172****	-0.0471****	-0.0145*	-0.0269***	0.0115
	(0.0039)	(0.0066)	(0.0077)	(0.0080)	(0.0070)
$\Delta \ln$(wind cap.)	-0.0026	-0.0037	0.0038	-0.0134	0.0059
	(0.0098)	(0.0145)	(0.0137)	(0.0151)	(0.0085)

	3. Medical benefits			*4. Other programs*		
	Total medical (3)	Medicare (3a)	Medicaid (3b)	UI (4a)	Social security (4b)	Education (4c)
$\Delta \ln$(solar cap.)	-0.0126*	-0.0077	-0.0186***	-0.0110	-0.0085**	-0.0066
	(0.0071)	(0.0076)	(0.0064)	(0.0317)	(0.0041)	(0.0066)
$\Delta \ln$(wind cap.)	-0.0003	0.0007	-0.0023	-0.0360	0.0000	-0.0337***
	(0.0107)	(0.0128)	(0.0107)	(0.0219)	(0.0078)	(0.0167)

Notes: Robust standard errors clustered at the state level in parenthesis. *, **, ***, and **** indicate statistical significance at 10, 5, 1, and 0.1 percent levels, respectively.

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Robustness

Net Generation instead of Capacity

Panel A. Effect on extensive margins of work

Dependent variable:	Δ ln(Employment)	Δ ln(Labor force participation)	Δ ln(Population)
	(1)	(2)	(3)
Δ ln (solar net generation)	0.0168***	0.0159***	0.0013
	(0.0053)	(0.0056)	(0.0055)
Δ ln (wind net generation)	0.0088	0.0087	0.0203
	(0.0114)	(0.0116)	(0.0141)
Number of observation	10,094	10,094	10,094

Robustness

Net Generation instead of Capacity

Panel B. Effect on other margins of work

Dependent variable:	Δ ln wage annually	Δ ln wage weekly	Δ ln wage hourly	Δ ln weeks worked per year	Δ ln hours worked per week
	(1)	(2)	(3)	(4)	(5)
Δ ln(solar net generation)	0.0120**	0.0160**	0.0219**	-0.0007	0.0015*
	(0.0047)	(0.0071)	(0.0089)	(0.0026)	(0.0007)
Δ ln(wind net generation)	-0.0092	-0.0093	-0.0243	-0.0021	0.0003
	(0.0085)	(0.0128)	(0.0191)	(0.063)	(0.0016)
Number of observation	10,094	10,094	10,094	10,094	10,094

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Robustness

Coal capacity retirement

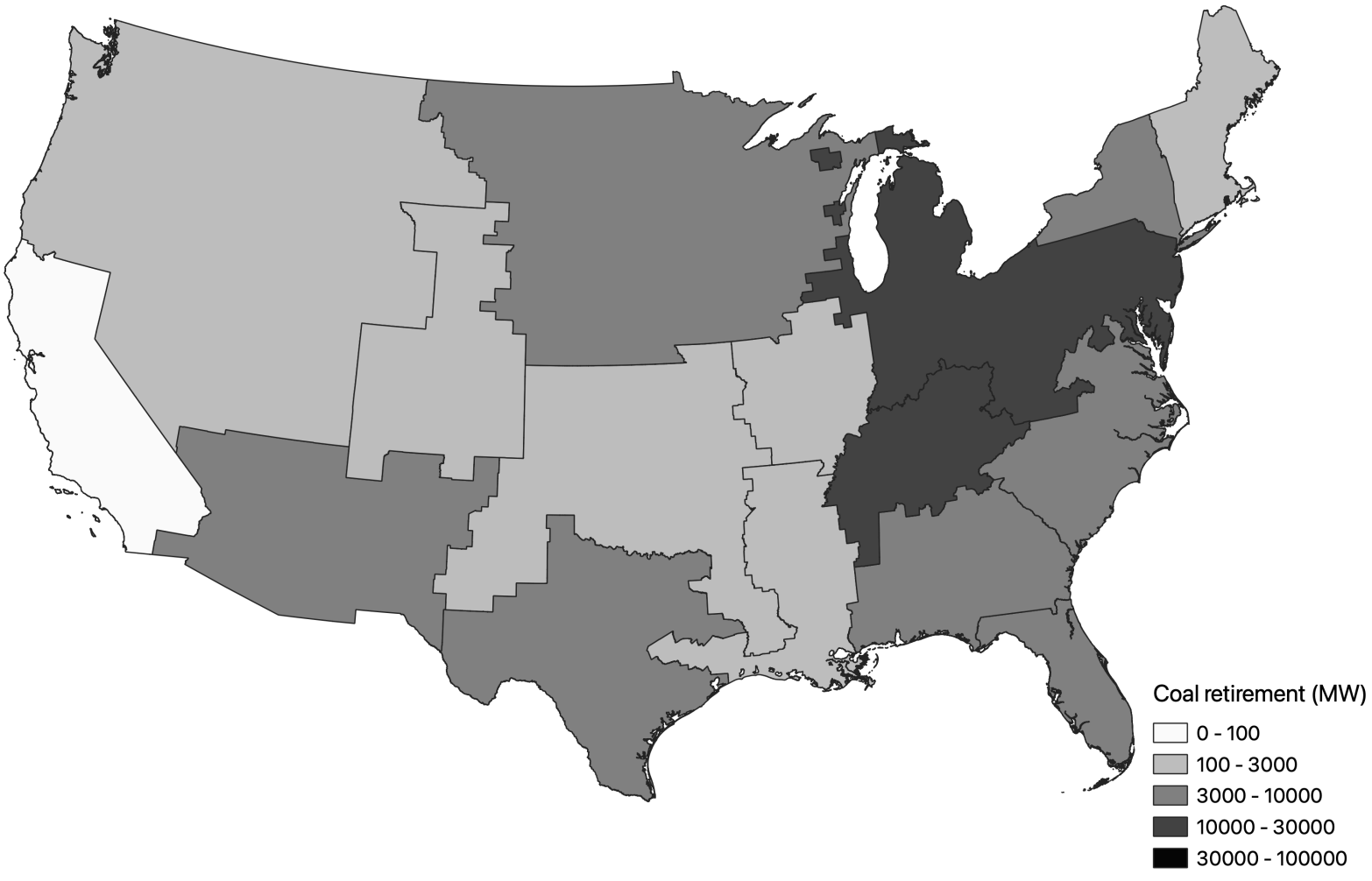

Figure: Changes in Coal-fired Generation Capacity (2001-2019)

Robustness

Coal capacity retirement as an additional shifter

Dependent variable:	Δ ln employment		Δ ln weekly wage	
	base (1a)	3 temporal shifters (1b)	base (2a)	3 temporal shifters (2b)
Δ ln (solar capacity)	0.0287****	0.0295****	0.0255****	0.0236****
	(0.0031)	(0.0044)	(0.0038)	(0.0004)
Δ ln (wind capacity)	0.0138**	0.0168**	-0.0011	-0.0008
	(0.0066)	(0.0066)	(0.0076)	(0.0069)
Number of observation	10,094	10,094	10,094	10,094
Sargan over-id. p-value	1.00	1.00	1.00	1.00

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Robustness

Longer differences

Panel A. Dependent variable: Δ ln employment

Time interval:	Every year (base)	Every 2 years	Every 3 years	Every 5 years	Every 7 years
	(1)	(2)	(3)	(4)	(5)
Δ ln (solar capacity)	0.0287****	0.0272****	0.0268****	0.0251****	0.0355****
	(0.0031)	(0.0025)	(0.0027)	(0.0035)	(0.0044)
Δ ln (wind capacity)	0.0138**	0.0138**	0.0163**	0.0174**	0.0218**
	(0.0066)	(0.0063)	(0.0077)	(0.0080)	(0.0082)
Number of obs.	10,094	5,047	3,605	2,163	1,442

Robustness

Longer differences

Panel B. Dependent variable: Δ ln weekly wage

Time interval:	Every year (base)	Every 2 years	Every 3 years	Every 5 years	Every 7 years
	(1)	(2)	(3)	(4)	(5)
Δ ln (solar capacity)	0.0246****	0.0226****	0.0239****	0.0179****	0.0214***
	(0.0044)	(0.0036)	(0.0043)	(0.0045)	(0.0065)
Δ ln (wind capacity)	-0.0004	0.0024	0.0056	0.0067	0.0095
	(0.0073)	(0.0076)	(0.0096)	(0.0100)	(0.0100)
Number of obs.	10,094	5,047	3,605	2,163	1,442

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