

# Cap and Trade and CO<sub>2</sub> Emissions: Was the U.S. Regional Greenhouse Gas Initiative (RGGI) Effective?

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# RGGI Program

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The Regional Greenhouse Gas Initiative (RGGI), the first Cap and Trade program for CO<sub>2</sub> emissions in the United States,

- Began: 2009
- 10 states: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont.
- Goal: Reduce regional CO<sub>2</sub> emissions from the electricity sector.
- Analysis completed for RGGI region and three sub-regions NY, NE, MD-DE
- Analyzed four annual per capita CO<sub>2</sub> emissions categories; total, total electricity sector, coal generated, and natural gas generated



# RGGI Regions

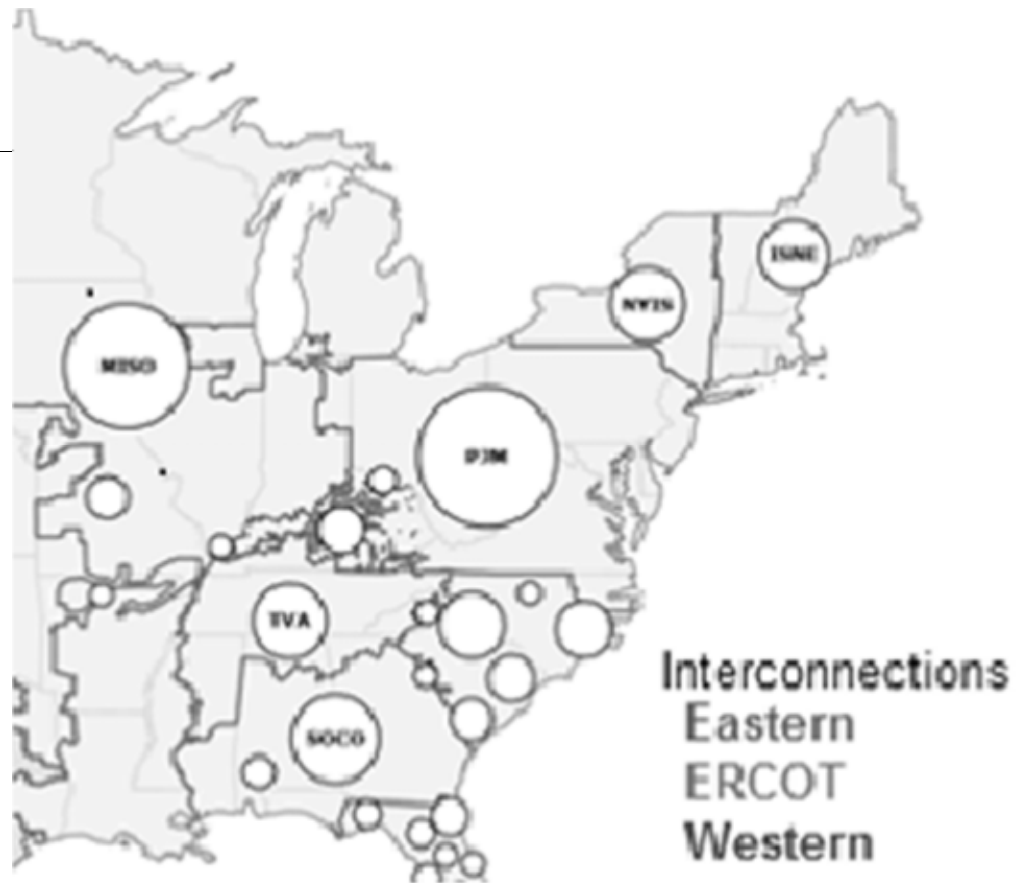
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## 1. Regional Separation

- New Jersey quit the program at the end of 2011

## 2. Balancing Authorities

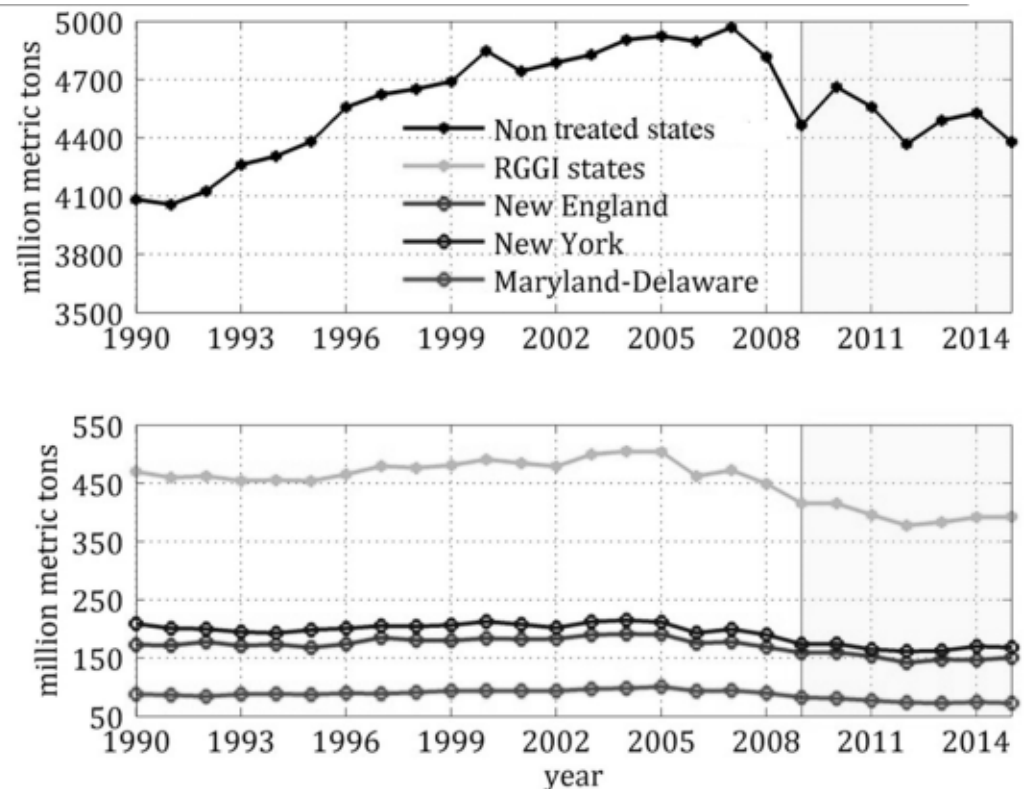
- ISNE (New England)
- NYIS (New York)
- PJM (includes MD-DE)



# RGGI: Success?

- According to the RGGI, as of 2016, member states had reduced electricity sector CO<sub>2</sub> emissions by more than 45 percent since 2005 (RGGI Investment, 2016).
  - On its own, this is an impressive statistic and seems to point to the success of the cap and trade initiative.
- However, the program did not begin until 2009 so any drop prior to its implementation is difficult to attribute to the policy change.
- Additionally, the cap was not binding until 2014, but there was a price floor of \$2 for emissions certificates.

## Electricity Sector CO<sub>2</sub> Emissions Levels



# Brief CO<sub>2</sub> Cap and Trade Literature Review

## ➤ EU-ETS (2005)

- Papers examining whether the EU-ETS has led to emissions reductions (Bel and Joseph 2015; Anderson and Di Maria 2011; Ellerman, Denny and Buchner 2008), research examining permit price (Koch et al 2016; Hintermann, Peterson, and Rickels 2015; Medina, Pardo and Pascual 2014; Aatola, Ollikainen, and Toppinen 2013; Hintermann 2011; Hintermann 2010), and work analyzing other market impacts from policy (Hintermann 2016; Rogge, Schneider and Hoffmann 2011).
- Bel and Joseph (2015)
  - Largest cause of emissions reductions from 2005 to 2012 was the 2008 economic crisis rather than the cap and trade market.

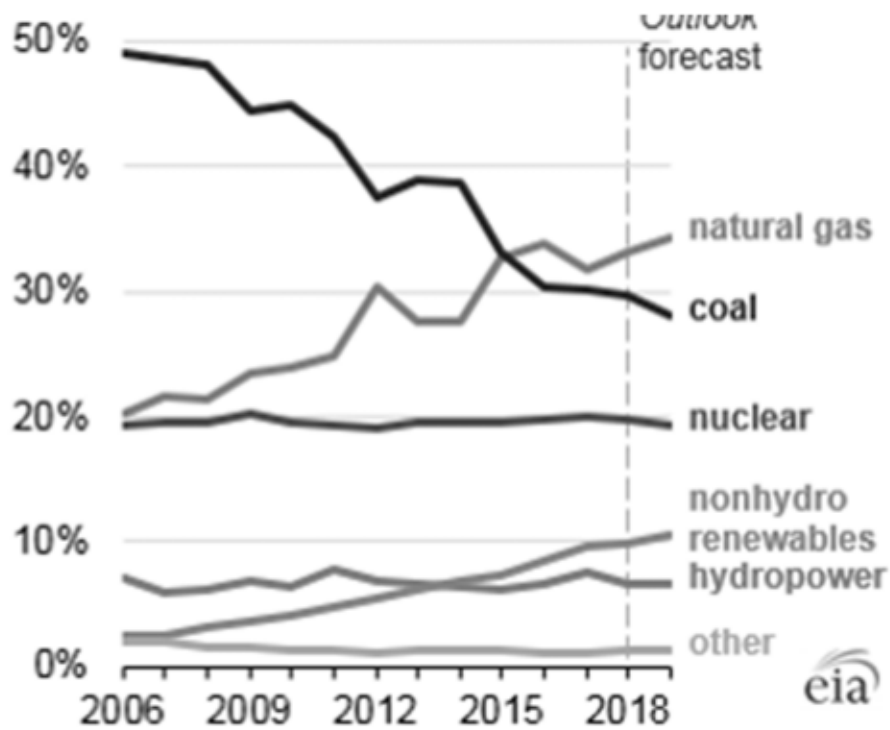
## ➤ RGGI success

- Murray and Maniloff (2015)
  - RGGI led to a 24% drop in CO<sub>2</sub> emissions
- Kim and Kim (2016)
  - Due to the RGGI, the share of natural gas in the region increased 10-15 percent

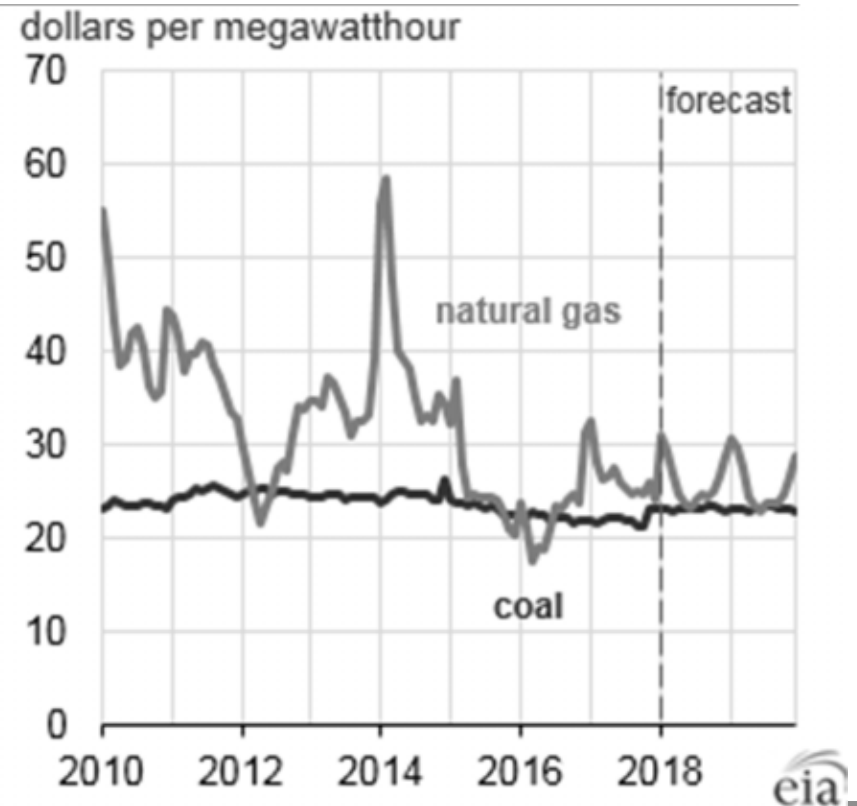
## ➤ RGGI Leakage

- Fell and Maniloff (2018)
  - RGGI policy led to a decline in coal generation in RGGI states, and a rise in natural gas generation in Ohio and Pennsylvania

U.S. electricity Generation by Energy Source 2006-2019: Share of Total Generation



U.S. Average Fuel Cost of Natural Gas and Coal Delivered to Electric Generators (2010-2019)



# Synthetic Control Method (SCM): Comparative Case Study Approach

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SCM (Abadie and Gardeazabal 2003; Abadie, Diamond and Hainmueller 2010)

- Create a weighted blend of control states that will become a “synthetic” control region
- By creating a counterfactual RGGI or sub-RGGI region, we are able to construct an appropriate control region, which does not exist
  - Pre-intervention matching over a long pre-intervention period (1990-2008) allows us to control for static and dynamic regional and electricity market characteristics

In this paper we compare outcomes in RGGI regions with states that did not have this policy (39 states)

- Exclude CA

## SCM: Synthetic Value for each Type of Emissions for RGGI Region

### Predictors

	Synthetic RGGI				Actual
	Total	Elec.	Coal	NG	
<b>CO<sub>2</sub> Emissions</b>					
Coal- to tot generation	0.07	0.11	0.15	0.40	0.24
NG- to total capacity	0.11	0.24	0.17	0.26	0.28
total net generation	16.08	16.10	16.09	16.34	15.90
Education: college	22.54	22.25	21.90	24.37	28.82
Commercial Sales	4.27	3.97	4.45	3.39	3.37
Personal income	3.33	3.40	3.32	3.52	3.62
Residential customers	39.65	38.35	41.27	38.05	38.06

### Robustness: Alternative Set of Predictors

	Synthetic RGGI				Actual
	Total	Elec.	Coal	NG	
<b>CO<sub>2</sub> Emissions</b>					
NG- to tot generation	0.11	0.03	0.27	0.14	0.22
Coal- to total capacity	0.07	0.07	0.08	0.31	0.16
% homeowners	69.25	60.44	65.42	59.53	58.87
Industrial Revenue	0.20	0.27	0.24	0.30	0.14
Total Sales	14.95	12.47	13.72	10.65	8.35
FDI	-6.30	-5.37	-5.38	-5.05	-5.72
Personal income	3.34	3.50	3.37	3.45	3.62
Residential customers	41.26	36.97	38.43	36.80	38.06
Industrial customers	0.60	0.21	0.54	0.15	0.13

Outcome Variable for all specifications included for years 1990,1991, 1994, 1997, 2000, 2003, 2006, 2008



	RGGI				New England			
State: w-weight	Total	Electricity	Coal	NG	Total	Electricity	Coal	NG
Alaska	0.00	0.28	0.00	0.12	0.00	0.07	0.00	0.09
Colorado	0.00	0.00	0.06	0.00	0.00	0.00	0.02	0.83
Florida	0.00	0.00	0.11	0.05	0.35	0.20	0.09	0.08
Georgia	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00
Hawaii	0.12	0.10	0.00	0.08	0.00	0.00	0.00	0.00
Idaho	0.69	0.49	0.73	0.00	0.36	0.59	0.78	0.00
Illinois	0.00	0.00	0.00	0.62	0.00	0.00	0.04	0.00
Missouri	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Nevada	0.00	0.13	0.00	0.13	0.00	0.07	0.00	0.00
North Carolina	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oklahoma	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Oregon	0.10	0.00	0.00	0.00	0.10	0.00	0.00	0.00
Pennsylvania	0.00	0.00	0.05	0.00	0.00	0.00	0.03	0.00
Texas	0.00	0.00	0.03	0.00	0.00	0.00	0.05	0.00
Virginia	0.04	0.00	0.00	0.00	0.09	0.00	0.00	0.00
Washington	0.03	0.00	0.00	0.00	0.10	0.00	0.00	0.00

# Placebo Tests and Significance

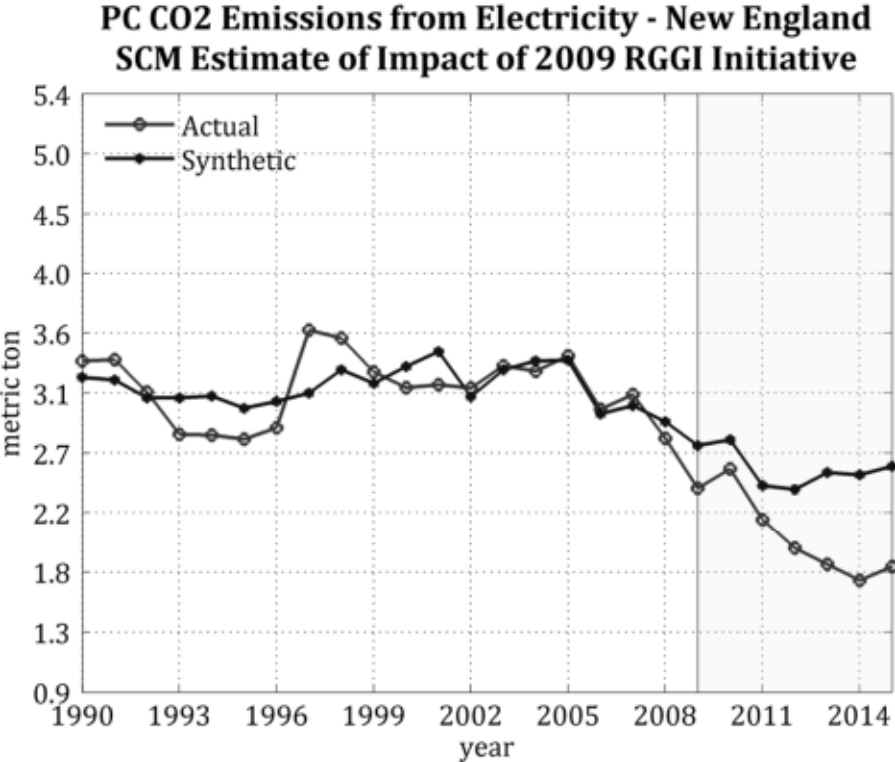
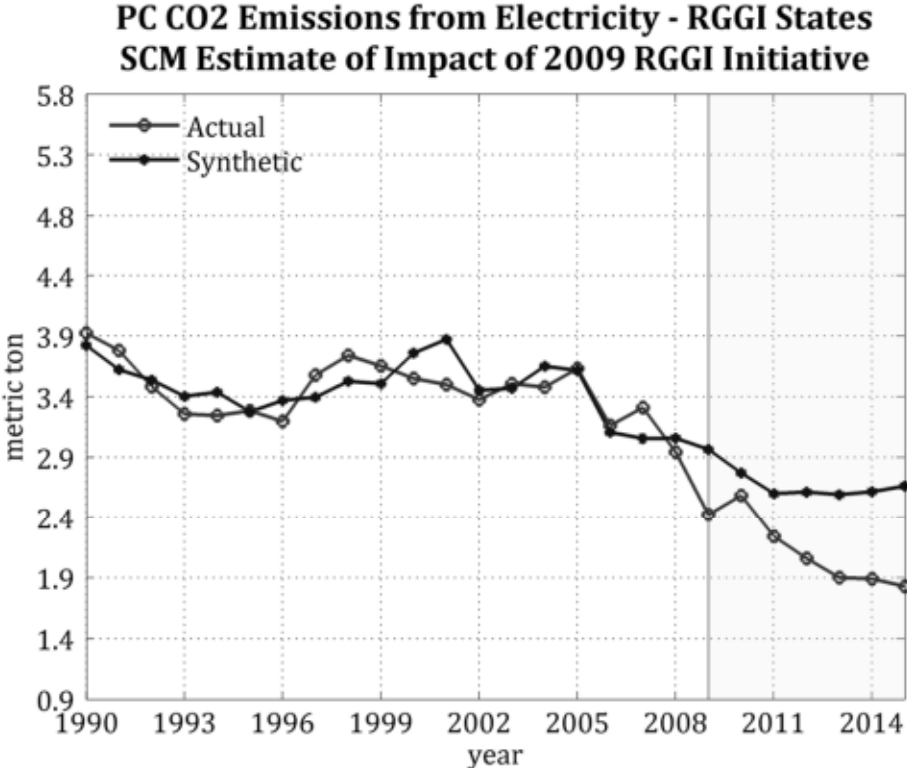
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To test the significance of this estimate, we apply the permutations or randomization test as suggested by Bertrand et al. (2004), Buchmueller et al. (2011), Abadie, Diamond and Hainmueller (2010) and Bohn et al. (2014).

For each state and in the donor pool, we estimate the impact of a fictitious (placebo) RGGI intervention in 2009.

- The distribution of these placebo estimates then provides the equivalent of a sampling distribution for the estimate for the treated region (Bohn et al. 2014, Munasib and Rickman 2015, Maguire and Munasib 2018).
- A rank of 1 indicates that the treated region had the largest post-intervention effect as compared to its pre-intervention match. I.e. no placebo region had a larger effect. This indicates statistical significance in SCM.

# RGGI and NE Estimates Test: Per Capita CO<sub>2</sub> Emissions

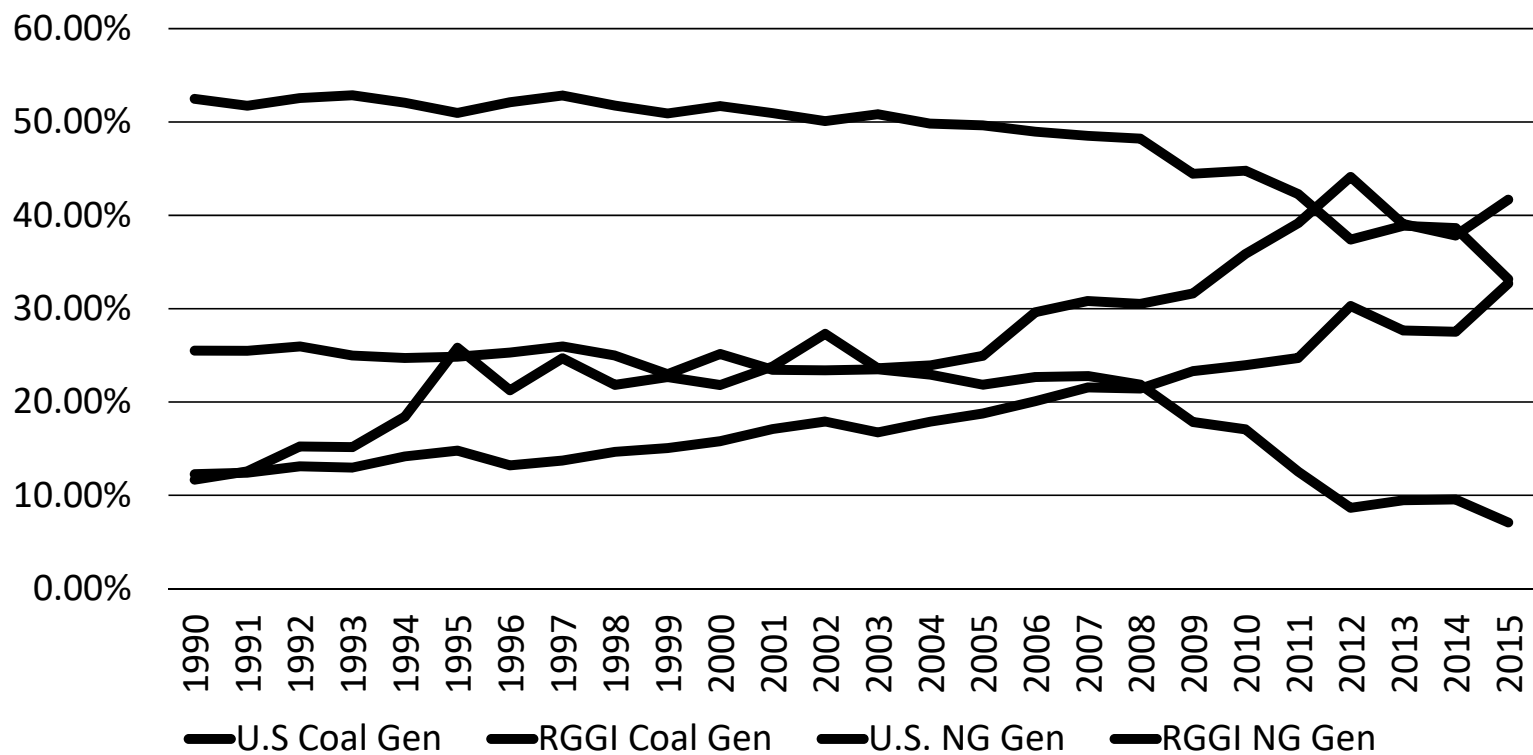


# Results: RGGI and NE Per Capita CO<sub>2</sub> Emissions

	RGGI (Entire Region)				New England			
Per Capita CO <sub>2</sub> Emissions	Total	Electricity	Coal	Natural Gas	Total	Electricity	Coal	Natural Gas
Pre-intervention RMSPE	0.33	0.16	0.03	0.07	0.39	0.20	0.07	0.14
Estimated Impact	-1.21	-0.55	-0.64	0.16	-0.69	-0.54	-0.60	0.22
Post-Pre RMSPE rank	8	11	1	27	22	15	1	30
Donor Probability	0.20	0.28	0.03	0.68	0.55	0.38	0.03	0.75

Findings with an alternative set of predictors were unchanged across emissions categories.

## U.S. and RGGI: Coal and NG Share



# Findings

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CO<sub>2</sub> emissions from coal-generated electricity declined by an annual average of 44 percent in the RGGI region.

For the New England and Maryland-Delaware regions CO<sub>2</sub> emissions from coal-generated electricity declined by an annual average of 57 and 29 percent, respectively.

Our estimated impacts of RGGI for New York, were not robust to alternative specifications, but are qualitatively the same as New England and Maryland-Delaware.

# Time Placebo: 2002

	Total	Electricity	Coal	Natural Gas	Total	Electricity	Coal	Natural Gas
	RGGI region				New England			
Pre-intervention RMSPE	0.26	0.21	0.04	0.13	0.44	0.25	0.08	0.07
Post-intervention difference	0.12	-0.33	0.15	-0.09	0.69	-0.33	0.24	0.19
<b>RMSPE Rank</b>	<b>27</b>	<b>26</b>	<b>7</b>	<b>40</b>	<b>20</b>	<b>27</b>	<b>11</b>	<b>25</b>
Donor probability	0.68	0.65	0.18	1.00	0.50	0.68	0.28	0.63
	New York				Maryland-Delaware			
Pre-int RMSPE	0.65	0.23	0.05	0.11	0.26	0.19	0.10	0.10
Estimated impact	-0.13	-0.51	0.15	-0.23	-0.17	-0.41	0.35	-0.30
<b>RMSPE Rank</b>	<b>39</b>	<b>23</b>	<b>9</b>	<b>31</b>	<b>23</b>	<b>22</b>	<b>10</b>	<b>26</b>
Donor probability	0.98	0.58	0.23	0.78	0.58	0.55	0.25	0.65

# Additional Tests: Leakage

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Rerun our main estimates by excluding all the states bordering the RGGI region.

- We exclude Ohio, Pennsylvania, West Virginia and Virginia from the donor pool.
- Similar findings. RMSPE Rank of 1 in all four regions for coal-generated CO<sub>2</sub> emissions, other emissions no significant effect from RGGI.

## Leakage Analysis

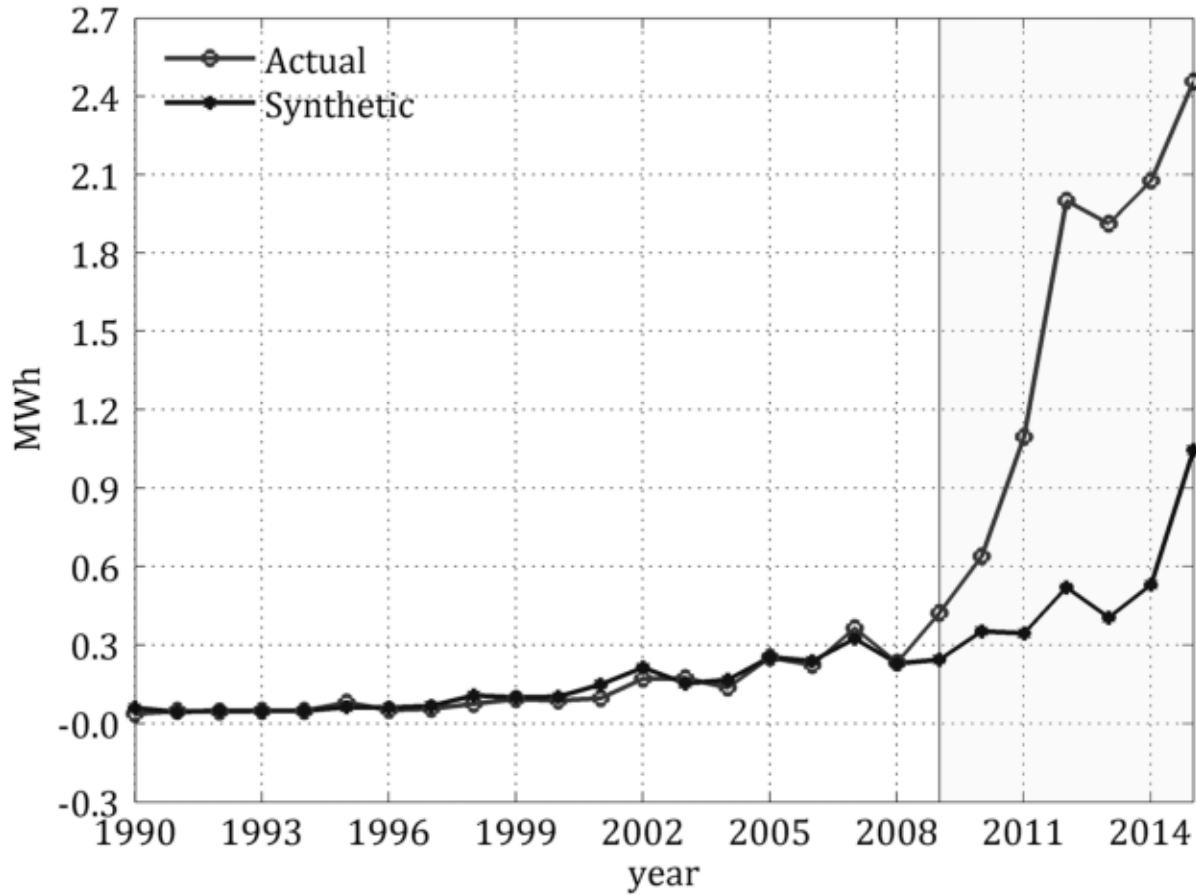
- We analyzed the impact of RGGI on electricity generation (total generation, generation from coal and generation from natural gas) in all four states bordering the RGGI states:
  - Ohio, Pennsylvania, Virginia and West Virginia

We find a statistically significant impact only in case of natural gas generation in Ohio.

- Doubling of electricity generation from natural gas caused by RGGI



### Per Capita Natural Gas Electricity Generation - Ohio SCM Estimate of Impact of 2009 RGGI Initiative



# Conclusions

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RGGI did not reduce overall CO<sub>2</sub> emissions through 2015, but led to a decrease in coal-generated CO<sub>2</sub> emissions in the RGGI region as a whole and in the NE and MD-DE subregions.

- This supports the work of Fell and Maniloff (2018) that found a reduction in coal generation in the RGGI region.

There wasn't increased coal generation in neighboring states due to RGGI, but there was increased natural gas generation in Ohio. Leakage?