Pricing Carbon, Powering Change: RGGI's Impact on Renewable Generation vs. ERCOT

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2025-04-02

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0.1 Abstract

This paper investigates the impact of carbon permit pricing under the Regional Greenhouse Gas Initiative (RGGI) on renewable energy generation, using a multiple linear regression lagged model framework to attempt to quantify the relationship between permit price, renewable share, and total renewable generation. By incorporating ERCOT;a large, deregulated electricity market without carbon pricing—into the analysis as our control observation, we assess the extent to which carbon pricing alone explains renewable energy deployment. The findings confirm that RGGI permit prices are significantly associated with increased renewable generation, supporting traditional economic theory that externality senesative pricing structures can influence market behavior. However, ERCOT is consistently producing higher renewable share despite the absence of carbon pricing highlights the importance of additional structural factors such as geographic resource advantages, market liberalization, and strategic transmission investment. These results underscore the need for a more advanced policy strategy to accelerate the transition to a low-carbon energy system.

0.2 Introduction & Research Question

This paper examines the relationship between carbon permit prices in the Regional Greenhouse Gas Initiative (RGGI) states and electricity generation patterns, while comparing these patterns with the Electric Reliability Council of Texas (ERCOT) system as a contemporaneous control. As states and regions implement varying approaches to carbon pricing and electricity market structure, understanding the resulting differences in generation mix, emissions intensity, and system reliability becomes increasingly important for policymakers and market participants (Environmental Defense Fund, 2022; Yan, 2021).

RGGI, is the first mandatory, market-based cap-and-trade program in the United States focused on reducing CO emissions from the power sector (RGGI, Inc., 2021). The program has been shown to not only reduce overall emissions but also raise revenue for reinvestment in more energy efficiency and renewable projects (Analysis Group, 2011; Massachusetts Government). Since RGGI spans multiple states and transmission organizations, we utilize ISO New England (ISO-NE) generation data as a proxy for RGGI renewable generation, this is de to coverage, accessibility, and significant overlap with core RGGI member states as well as cela formatted data and complete datasets (ISO New England Inc.).

By comparing RGGI outcomes with those of ERCOT, this study attempts to isolate the potential causal influence of permit pricing on renewable energy deployment.

0.3 Data & Methodology

We utilize quarterly RGGI auction clearing prices from September 2011 to March 2025, hourly ERCOT generation data by resource type, and detailed market data from NE-ISO. These sources provide a full picture of electricity generation patterns through time series data and carbon permit dynamics. Summary statistics, detailed descriptions, and methodological challenges, such as integrating PJM data and accounting for confounding variables, are provided in the appendix (see Appendix A).

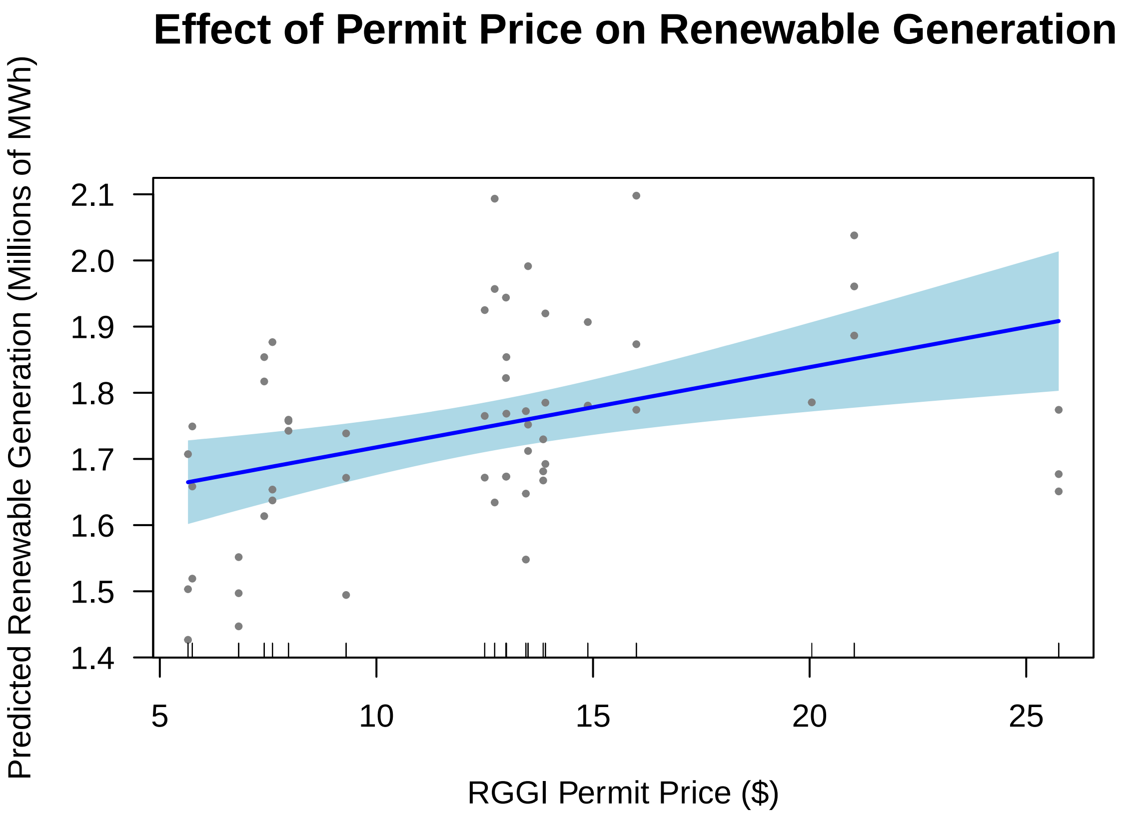
Model Specification We estimate the following multiple linear lagged regression model to evaluate the impact of RGGI permit prices on renewable generation controlling for time dependant componenets:

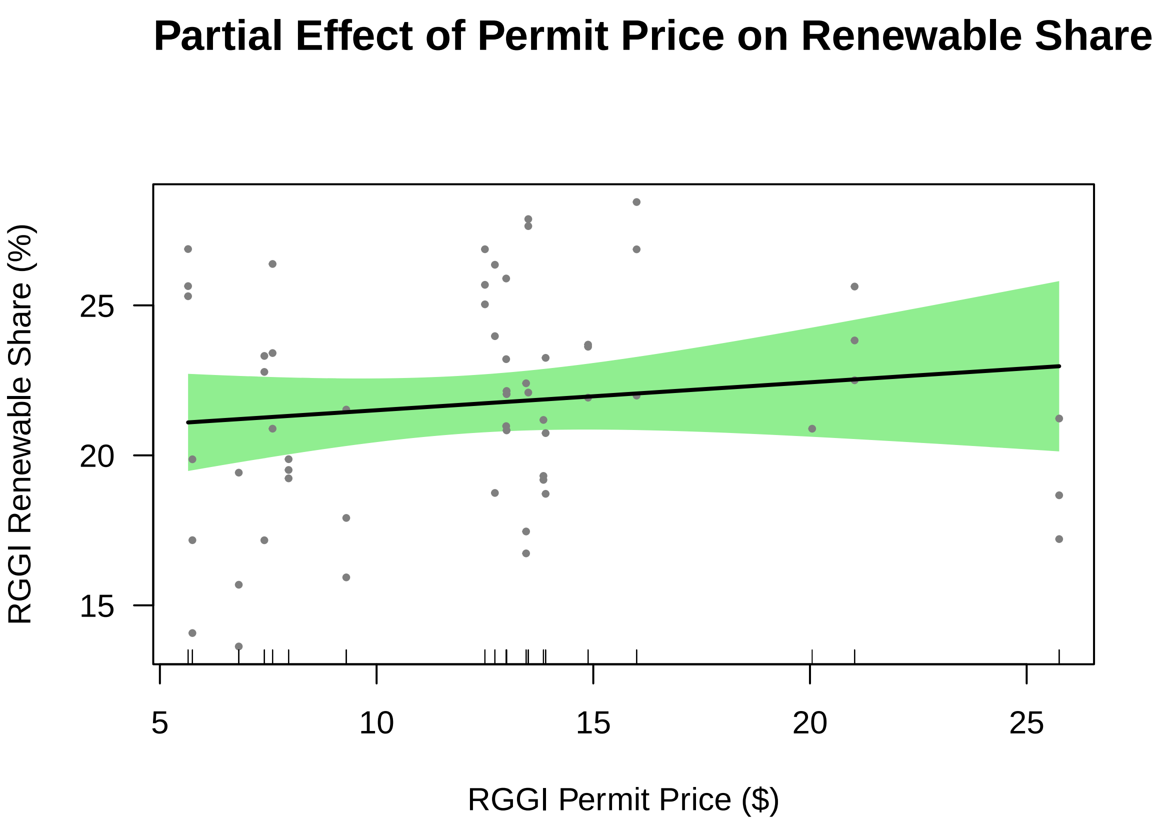
$$\widehat{\text{RGGI Renewable Generation}}_t = \beta_0 + \beta_1 \cdot \text{Permit Price}_{t-1} + \beta_2 \cdot \text{Renewable Share}_t$$

where Y_t is renewable generation at time t, Permit Price_{t-1} is the lagged permit price, and Renewable Share_t is a contemporaneous control variable. The lagged permit price controls for delayed effects and reduces random correlation due to correlated or cointegrated trends.

0.4 Results

The model was statistically significant, $F(2, 54) = 96.87$, $p < 2.2 \times 10^{-16}$, explaining 78.2% of the variance in renewable generation ($R^2 = 0.782$). For each one-dollar increase in lagged RGGI permit price, renewable generation increased by an estimated 12,300 MWh (β = 12,300, $p = 0.002$), controlling for renewable share. Renewable share was also a strong predictor, with a one-unit increase associated with a 5.18 million MWh increase (β = 5,176,292, $p < 2 \times 10^{-16}$). Full regression results are included in Appendix B.





The above figures illustrate the effects more clearly and predictive power of Permit price effect on renewable generationa nd share respectivlty.

0.5 Discussion & Conclusion

Our statistical analysis confirms that RGGI permit prices are positively associated with renewable generation, supporting the claim of effectiveness for carbon pricing systems in providing incentive for cleaner energy production (Environmental Defense Fund, 2022; Yan, 2021). However, ERCOT's higher renewable share despite no carbon pricing—suggests that structural factors like infrastructure and geolocation are critical drivers for overall generation outside of applied pricing matrix creations, like a cap and trade. (Analysis Group, 2011; see Appendix C for detailed comparison). A control model using ERCOT data found no significant relationship between RGGI permit prices and ERCOT renewable generation, validating our main findings (see Appendix B). These results indicate that while carbon pricing is overal effective, a more sophisticated approach combining pricing with institutional reforms and strategic investment is essential for de-carbonization. Pricing alone may never reach the desired effect unless compounded over a extended period of time, therefore to speed up the rate of de-carbonization more must be applied rahther than jsut eoncomcis pricing theory methods to ensure the growth rate of clean energy is exponentiated enough to meet goals.

0.6 Appendix

1 Appendix A: Data Details and Summary Statistics

Data Sources and Methodological Challenges RGGI: Quarterly auction clearing prices from September 2011 to March 2025.

ERCOT: Hourly generation data by resource type.

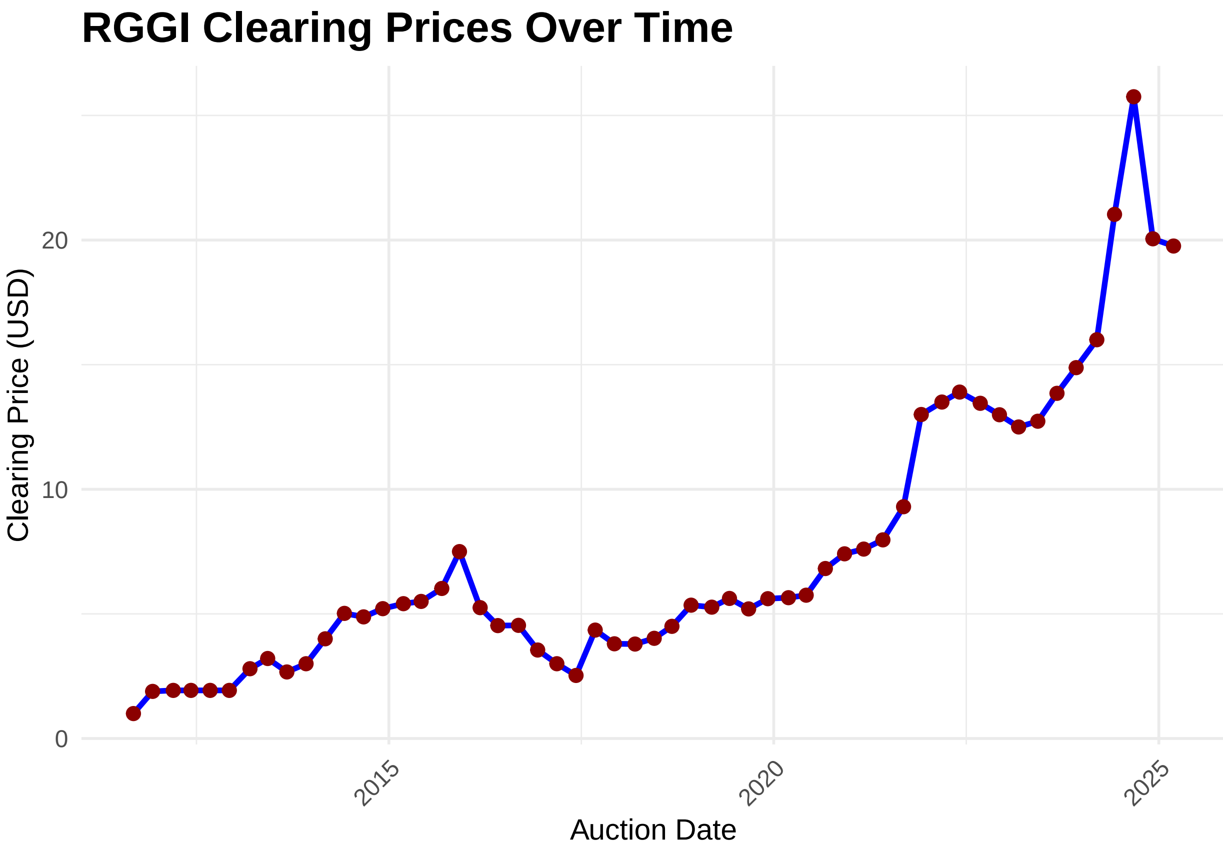
NE-ISO: Detailed market data. Challenges included integrating PJM data due to partial RGGI overlap causing a concern fir over fitting in a model with no coross validation etc.. There also is an issue controlling for confounders like gas prices and weather, addressed via statistical methods and AI-assisted data processing. Important to note AI was **only** used to clean data for NA values and repetitions and was also used to enhance the visuals of graphs, not for any idea generation or methodological decisions like choice of statstical tools/models in this paper.

Summary Statistics for RGGI Clearing Prices

Table 1: Table A1: Summary Statistics for RGGI Clearing Prices (USD)

Statistic	Value
Min.	$1.00
1st Qu.	$3.80
Median	$5.35
Mean	$7.47
3rd Qu.	$10.90
Max.	$25.75

Plot of Permit Prices Over Time



Summary Statistics for ERCOT Generation

Table 2: Table A2: Summary Statistics for ERCOT Generation by Source

Source	Count	Mean (GWh)	SD	Min	Q1	Median	Q3	Max
Biomass	60	35	21	6	18.8	25.5	58.2	75
Coal	60	5,582	1,191	2,917	4,870.2	5,529.0	6,416.8	8,192
Gas	60	2,573	1,416	673	1,394.5	2,320.0	3,487.0	7,195
Gas-CC	60	12,860	3,476	7,023	10,199.8	12,005.5	15,733.2	20,196
Hydro	60	38	24	8	17.0	31.0	54.5	96
Nuclear	60	3,381	378	2,178	3,167.8	3,444.5	3,696.2	3,803
Other	60	63	79	-3	0.0	51.0	78.5	333
Solar	60	2,155	1,350	361	1,077.5	1,841.0	3,004.2	5,827
WSL	36	-125	95	-407	-161.5	-83.0	-63.8	-33
Wind	60	8,492	1,653	5,029	7,375.0	8,421.0	9,616.0	12,454

Plot for ERCOT Generation by Fuel Type

Plot for NE ISO Generation by type

Summary Statistics for ISO NE Generation

Table 3: Table A3: Summary Statistics for RGGI ISO Generation by Type (MWh)

Generation Type	Obs.	Total	Mean	Median	SD	Min	Max
COAL	60	1,438,965	23,983	5,984	46,617	14.8	253,853
GAS	60	273,444,500	4,557,408	4,365,388	1,045,874	2,752,009.5	6,917,898
HYDRO	60	40,679,356	677,989	687,954	199,776	253,753.8	998,469
LANDFILL GAS	60	2,141,025	35,684	36,813	5,161	13,973.0	41,195
METHANE	60	193,478	3,225	3,265	374	2,356.5	3,985
NUCLEAR	60	129,788,422	2,163,140	2,343,504	437,543	923,854.3	2,500,501
OIL	60	2,864,685	47,745	7,691	148,417	447.8	1,030,184
OTHER	60	800,853	13,348	5,795	14,015	1,847.6	46,205
PRD	60	111,037	1,851	1,292	2,067	2.7	13,261
REFUSE	60	14,142,953	235,716	232,411	17,605	193,023.5	270,450
SOLAR	60	16,767,151	279,453	268,483	124,846	79,797.8	537,986
STEAM	60	0	0	0	0	0.0	0
TOTAL	60	510,478,353	8,507,973	8,359,116	1,113,091	6,210,305.7	11,350,005
WIND	60	35,840,387	597,340	595,021	177,032	264,634.0	940,363
WOOD	60	10,186,124	169,769	168,921	40,977	53,202.0	249,942

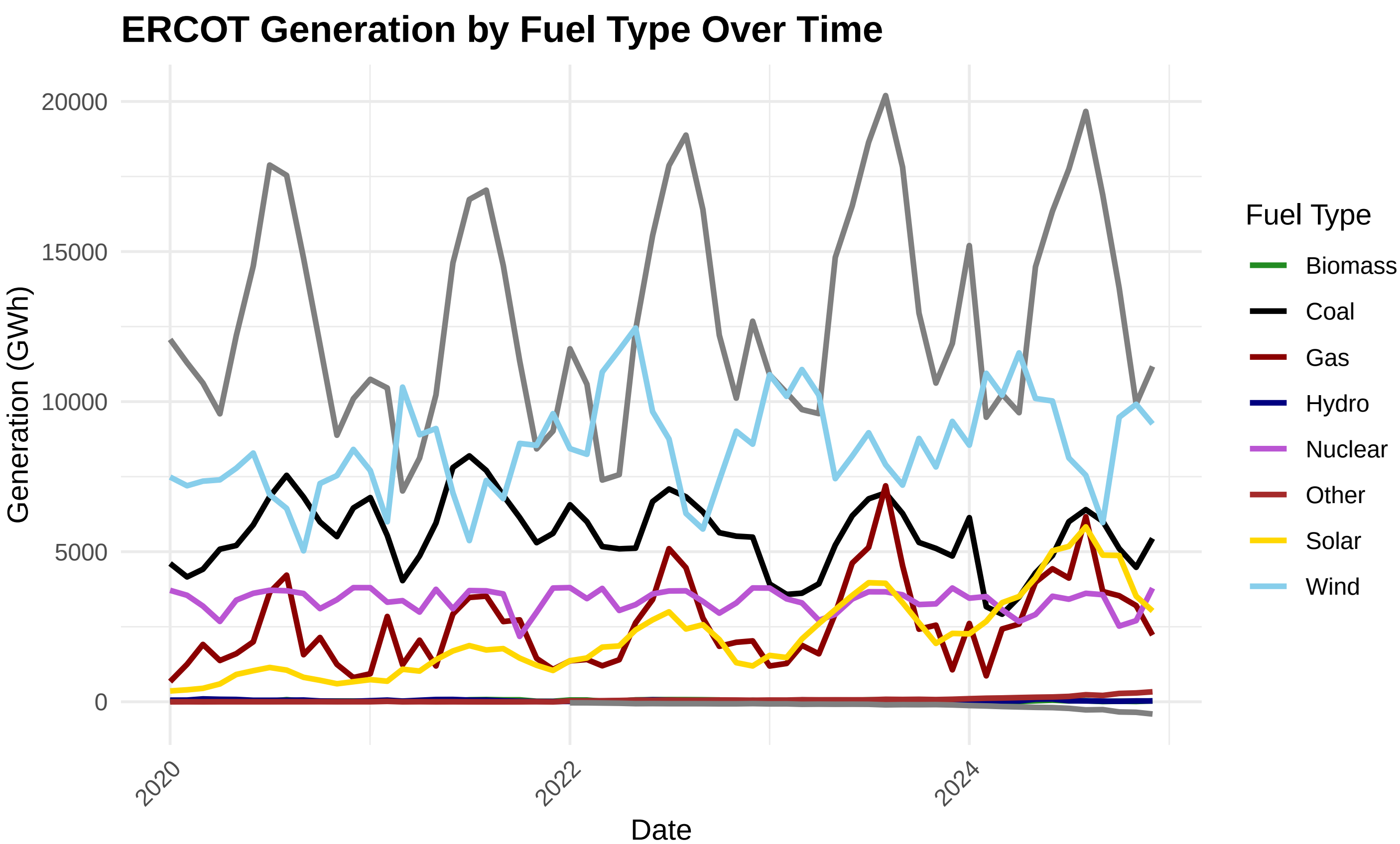


Figure 1: Figure A1: ERCOT Generation by Fuel Type Over Time

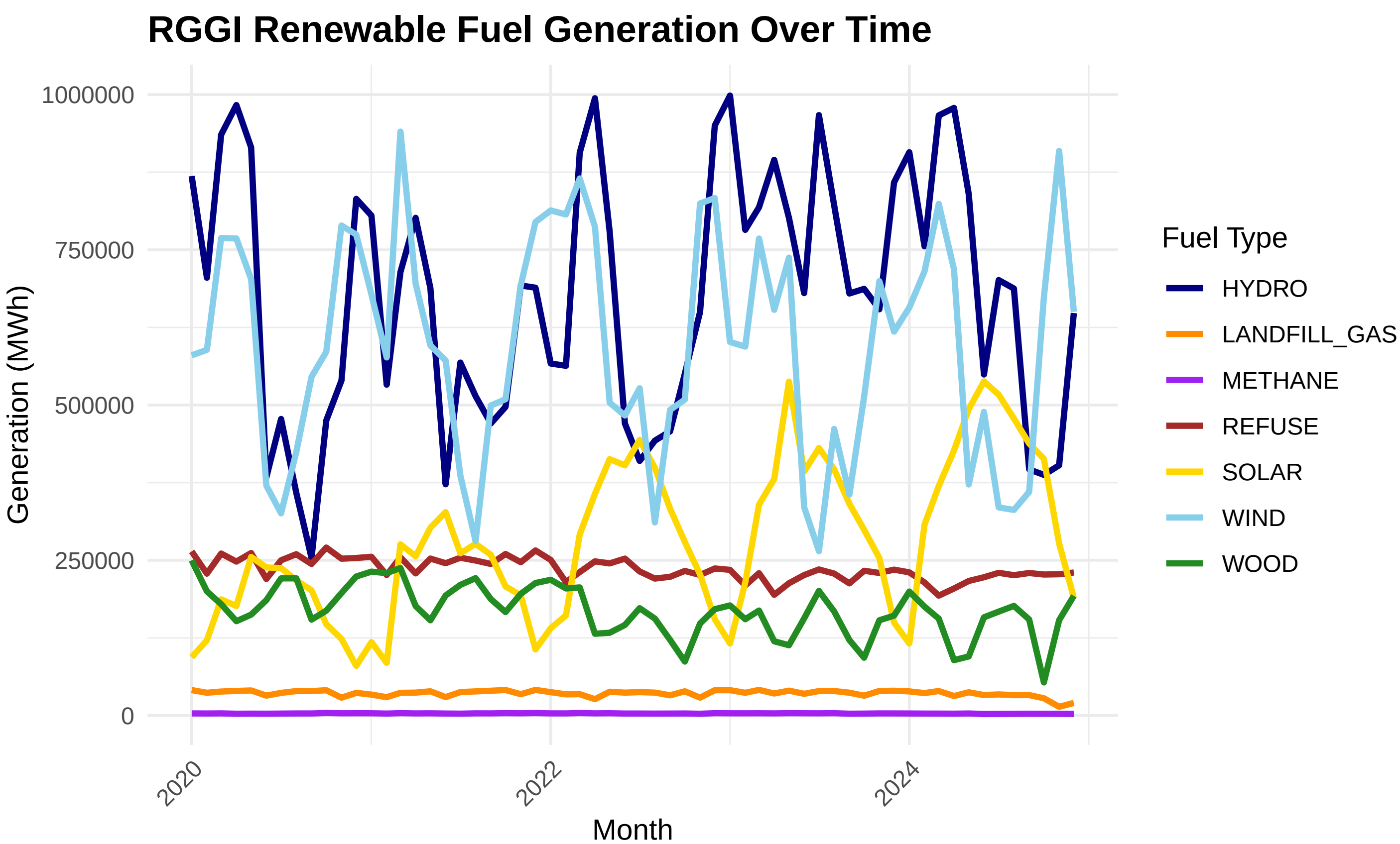


Figure 2: Figure A2: RGGI Renewable Fuel Generation Over Time

Table 4: Table B1: Control Model

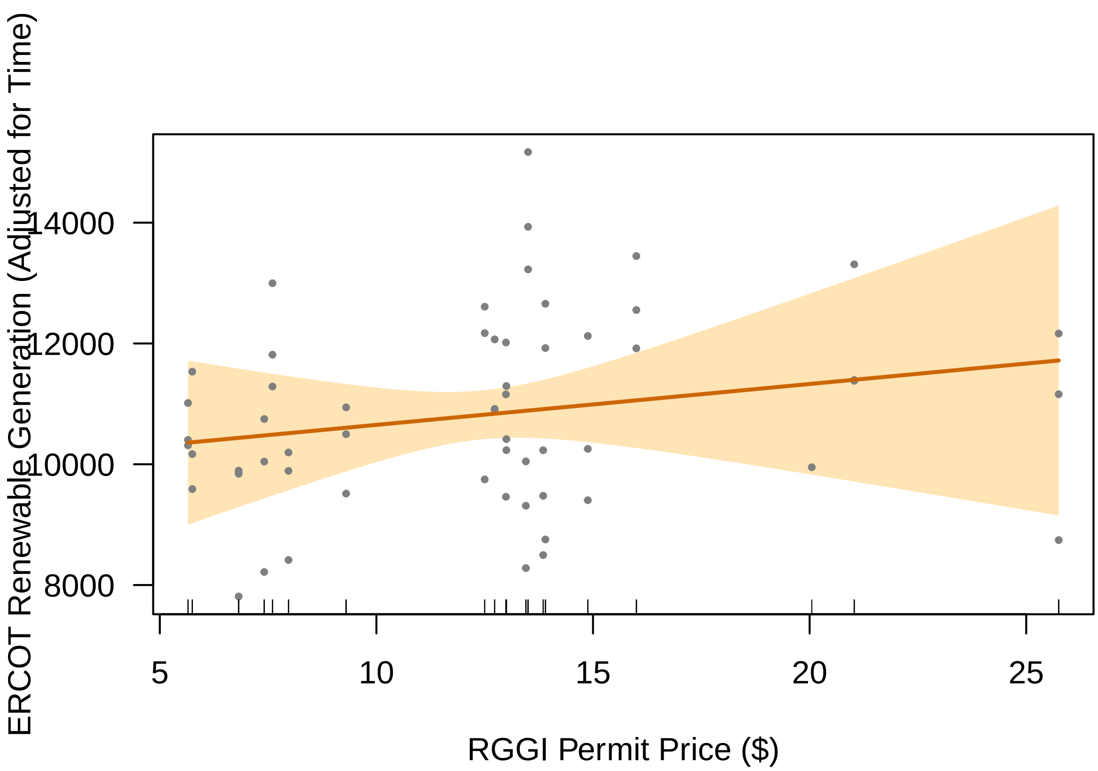
	(1)
(Intercept)	$-42\,885^{*}$
	(17 089)
RGGI_Permit_Price	68
	(95)
Time_Index	3^{**}
	(1)
Num.Obs.	58
R2	0.569
RMSE	1497.77

+ p <0.1, * p <0.05, ** p <0.01, *** p <0.001

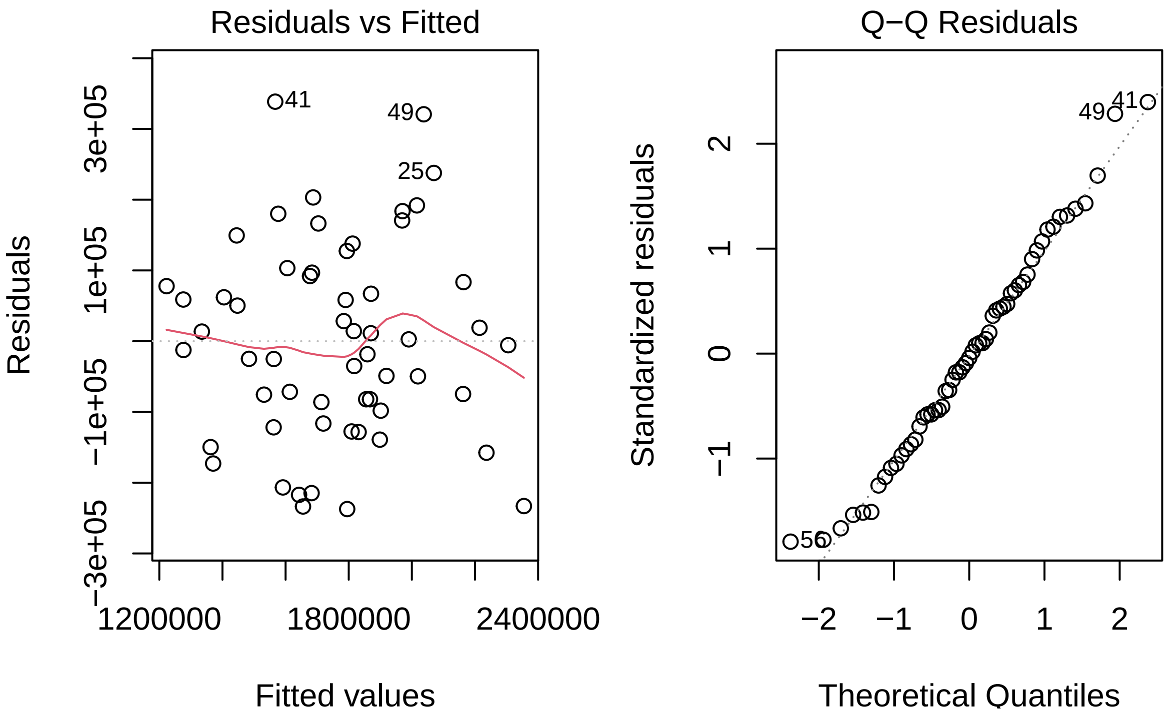
2 Appendix B: Robustness Checks

Control Model: ERCOT as a Non-RGGI Counterfactual

$$\text{ERCOT Renewable Generation}_t = \beta_0 + \beta_1 \cdot \text{RGGI Permit Price}_t + \beta_2 \cdot \text{Time Index}_t + \epsilon_t$$



Model Assessment



Additional Model Results

Table 5: Table B2: Full Regression Results

	Lagged Permit Price Model					
term	estimate	std.error	statistic	p.value	conf.low	conf.high
(Intercept)	516847.08	96933.08	5.33	0	322507.96	711186.19
RGGI_Permit_Price_Lag1	12299.81	3795.51	3.24	0	4690.27	19909.36
RGGI_Renewable_Share	5176291.87	376610.64	13.74	0	4421233.01	5931350.74

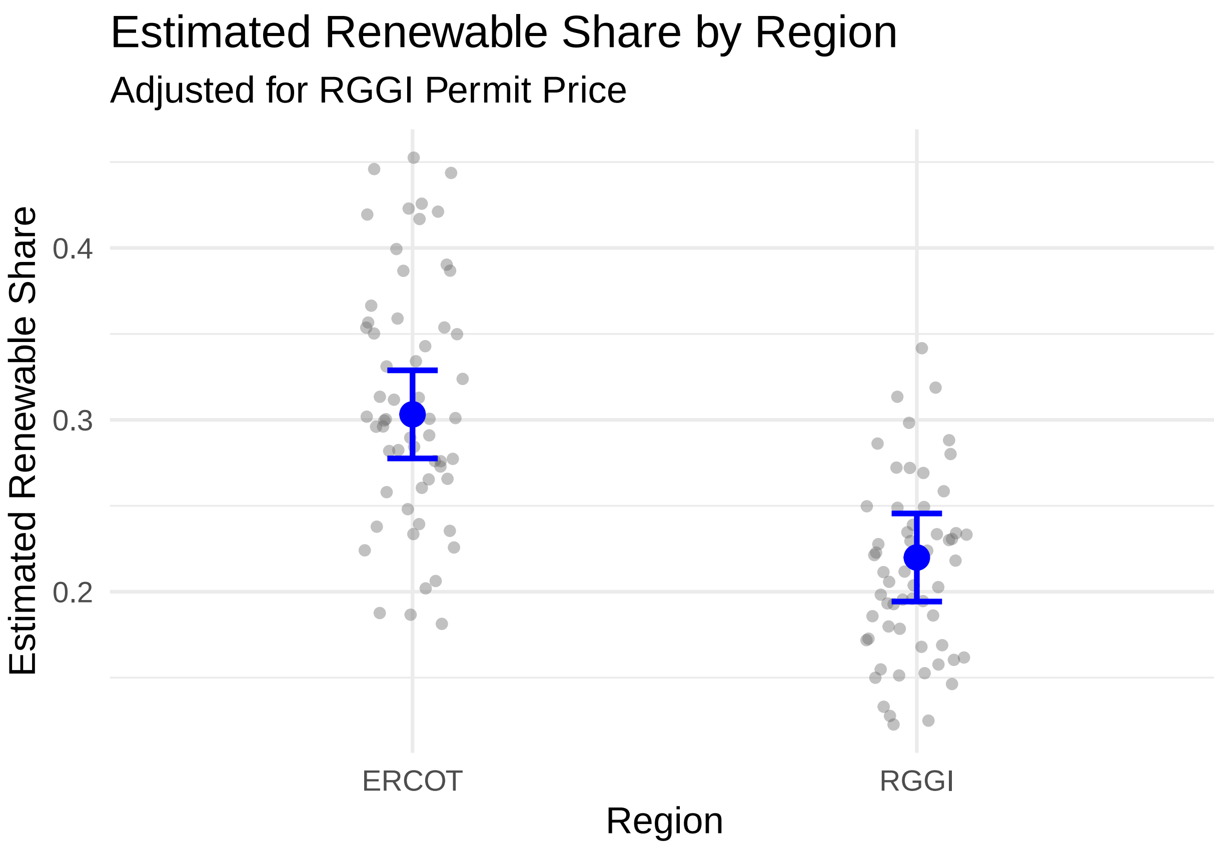
Num. Obs = 57; R^2 = 0.782; RMSE = 143202.21

3 Appendix C: Comparative Model (ERCOT vs RGGI)

$$\text{Renewable\_Share}_i = \beta_0 + \beta_1 \cdot \text{Permit\_Price}_i + \beta_2 \cdot \text{Region}_i + \epsilon_i$$

Table 6: Table C1: Estimated Renewable Share by Region (Adjusted for Permit Price)

Region	emmean	SE	df	lower.CL	upper.CL
ERCOT	0.303	0.013	113	0.278	0.329
RGGI	0.220	0.013	113	0.194	0.246



4 Appendix D: References

5 References

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