Labor Reallocation and the Regional Greenhouse Gas Initiative *

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Abstract

Policies intended to reduce the amount of greenhouse gas emissions are among the most hotly debated policy problems of our time. Among the concerns raised are that costs will be passed on to consumers and jobs will be lost. We use the introduction and eventual tightening of the Regional Greenhouse Gas Initiative (RGGI), a regional carbon permit system in the Northeastern United States, to measure labor market responses and dynamics following the implementation of a carbon pricing system. We find that implementation of the RGGI and the subsequent tightening of the emissions cap has had no effect on employment or earnings in the utilities sector but increased the rate at which workers flow in and out of jobs. In particular, within the utilities sector, we observe some job destruction and worker separation combined with increased labor reallocation across establishments. This is complemented with small spillover effects yielding positive increases in hiring, worker reallocation and job creation in industries outside of utilities. Furthermore, when we account for the endogeneity of electricity prices we find increased hiring, job creation and worker reallocation rates and a decline in job destruction rates across industries.

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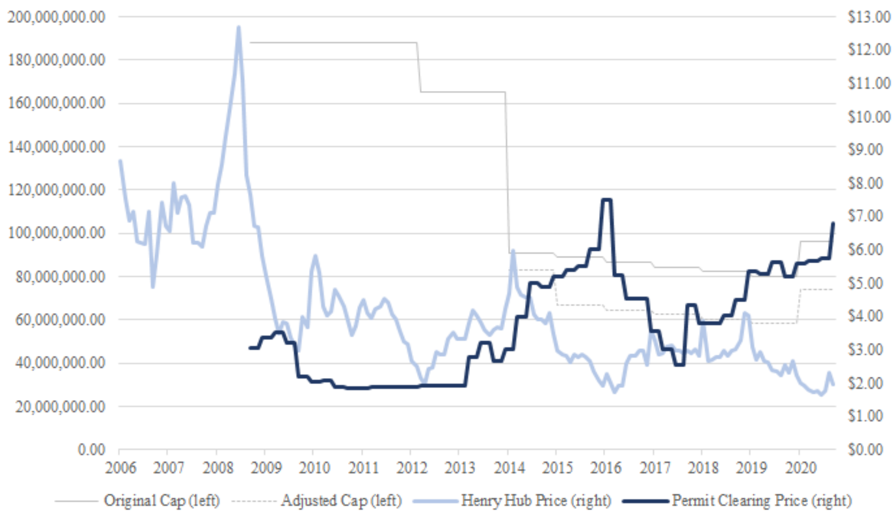
1 Introduction

Scientific evidence linking carbon dioxide emissions and global climatic change has accumulated for more than a century (Foote (1856)). Despite this, efforts to combat greenhouse gas emissions have been stymied at all levels of governance, and the policies that have been adopted are mostly regionally-based – especially in the United States. The reticence to adopt market-based policies that limit the negative externality effect of greenhouse gas emissions persists despite a canonical and widely accepted position, at least among economists, that market-based mechanisms will efficiently internalize negative externality effects. Much of the hesitation in adopting policies that put a price on carbon emissions revolves around negative impacts on labor markets and higher energy prices in all sectors, both of which are expected to lead to job loss. In this research, we study how labor markets have responded to the introduction of the first carbon permit trading system in the United States, the Regional Greenhouse Gas Initiative (RGGI), which has already extracted more than $3 Billion in carbon permit fees.

The RGGI was the first cap and trade system for carbon dioxide emissions put in place in the United States, and this carbon trading system has been in force since 2009. The RGGI policy covers emissions from the electric power sector only. When the policy began, the RGGI implemented a carbon cap of 188 million allowances for the 10 state region, and those allowances have tightened incrementally each year. The original coalition of 10 states included Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. In 2012 New Jersey left the coalition but rejoined the RGGI in January 2020. The state of Virginia joined the RGGI in January 2021, and Pennsylvania has passed a policy to begin the process of joining the RGGI as well.

In the time since the policy's original implementation, the nine states within the RGGI voted in 2013 to lower their emissions caps even further beginning in 2014. This was done because

Figure 1: RGGI Cap Levels, Permit Clearing Prices, and Natural Gas Prices



the emissions cap was effectively non-binding due to an unanticipated abundance of cheap natural gas, and hence lower emissions due to fuel substitution away from coal. For example, the original 2019 cap was 80,179,708 allowances – 42.6% of the emissions allowances in 2009. The 2014 revision of the RGGI adjusted the cap for 2019 to 58,288,301 allowances – 31% of the 2009 level. The evolution of emissions caps and lower natural gas price landscape can be seen in Figure 1.

Figure 1 shows how the total amount of allowances have changed over time both for the original cap and the adjusted cap. Also shown in this figure is the history of permit clearing prices and the wholesale price of natural gas, the 'Henry Hub' price. It is clear that permit prices have increased following the policy change to a lower emissions allowance cap - a nearly threefold increase in the market clearing price since the earlier periods of the RGGI. This visual evidence implies that there is now a tighter market for emissions allowances.[1] Interestingly, until recently it appears that permit prices followed natural gas prices with a time-lag. This makes intuitive sense given the potential for inter-fuel substitution away from natural gas to coal which has a higher carbon content per unit of heat. However, since

[1]The cap notches upwards in 2020 to reflect the re-entry of New Jersey into the coalition.

2017 permit clearing prices have increased steadily despite the low and declining price of natural gas. This price behavior is consistent with both a lower supply of allowances, and expectations of increased demand from new entrants into the permit system. Now, after 49 quarterly auctions in the eleven year tenure of the policy, more than $3.7 Billion has been collected in carbon fees which have been proportionally dispersed back to the states that purchased the carbon allowances. These permit revenues have been used to fund activities such as energy efficiency audits and improvements, renewable energy development, and low-carbon city services.[2]

In this research, we measure how labor markets have responded to the internalization of carbon dioxide externalities in the electric power sector. The RGGI area is the first to explicitly price carbon dioxide emissions from electricity generating sources within the United States, and surrounding states do not have carbon dioxide pricing. Moreover, there is not a Federal-level policy to limit these emissions. Hence, we are able to measure the effect of carbon pricing on labor market outcomes and dynamics while controlling for unobserved heterogeneity in state-industry makeup while also accounting for global factors that affect RGGI and non-RGGI states alike.

Our approach to answering how labor markets have been impacted by carbon-pricing adopts several empirical strategies, but all take advantage of a rich panel data structure with increasingly granular industry specifications, as well as structural modeling of the carbon-price pass-through. Additionally, we expand on standard practice that measures how employment and earnings might have changed by including outcome variables that measure the rates of job creation, job destruction, hiring, separation, worker reallocation, and job reallocation.

We begin our analysis by measuring how these labor market outcomes have evolved over time as a result of 1) the adoption of the RGGI carbon market as an initial policy treatment

[2] A report on state by state investments is available in RGGI (2016).

and 2) a second policy treatment that identifies when the carbon cap was lowered. Including two treatment periods is important in our setting because we can separately identify impacts of carbon pricing when the permit price is low and non-binding, as well as impacts when the price now has a greater effect at the margin and industries are many years removed from the Financial Crisis. In our analysis, we measure changes in employment, earnings, and various measures of job flows for: within the electric power sector, for all industries in the state, and within specific sectors, Industrial and Commercial, at the four digit and six digit NAICS industry level of detail. We drill down within to the electric power sector because this is the industry that is directly targeted by the new carbon-market system, however it is of broad policy importance to measure changes in other industries because electricity is an input in nearly all sectors and there maybe spillover effects.

Contrary to commonly held concerns, we do not find that the implementation of the carbon permit market, or even the tightening of carbon standards, have changed employment or earnings in affected industries. This null result is robust to multiple model permutations, control group specifications, and even holds when we estimate models at the most granular industry-level possible. The discernible impacts of the carbon permit system on labor markets that we find are 1) increases in job destruction and worker separation combined with increased job reallocation across establishments within utilities and 2) small spillover effects in non-utilities yielding increased job creation rates, hire rates, separation rates, and worker reallocation rates in RGGI states relative to non-RGGI states.

In order to determine the robustness of our results we supplement this work with a structural model of cost pass-through to fully account for dynamics in the energy market at the time that the RGGI was implemented. Here, we modify our baseline model to capture how electricity prices change over time by sector and state. In this model our estimates of the effect of the RGGI hold constant substitution and scale effects associated with electricity prices changes that may have occurred with the implementation of the RGGI. This model is identified by using contemporaneous and lagged wholesale natural gas prices and carbon expenses as instruments. Even in models that include the price of electricity we still find largely null results for employment and earnings, though there is weak evidence that employment in industrial sectors decreased following the implementation of the carbon market (though not for the cap tightening). Indeed, the main conclusions from before continue to hold: it is primarily through increased labor market churn that we notice RGGI-states differing from non-RGGI states. Here we see that job creation rates, hiring rates, and worker reallocation rates are all higher due to the implementation and tightening of the carbon permit system.

In addition to the instrumental variables model, we briefly examine policy spillover effects in neighboring states and we include robustness measures that alter the set of control state-industries. Here, we reduce the states included in the treatment-free comparison group by limiting the sample to only states that are outside of the Eastern Interconnection system so that there is not a possibility of having a tainted control group.[3] All of our primary results are unchanged when limiting the pool of treatment-free comparison group states, and if anything, there is evidence of improved employment and earnings in RGGI states. Final robustness models include an event-study analysis to account for potential pre-existing trends, and a triple difference-in-differences model. In the latter robustness exercise we leverage our ability to measure changes in the utilities and non-utilities industries within the RGGI region relative to those same industries in non RGGI states. Here, we see that there have been disruptive effects within the utilities sector. We find that employment and earnings are unchanged, but that there is increased job destruction, separations, and job reallocation.

[3]There are three main grids in the United States, the Eastern Interconnection, Western Interconnection, and the Electric Reliability Council of Texas. In each system electricity flows in a different phase, and 'importing' of electricity from grid-to-grid generally does not occur.

2 Labor market effects of environmental policy

The availability of research on the labor market impacts of carbon dioxide emissions policies is limited because few policies have been enacted, and those that have been passed are of a recent vintage. Indeed, to the best of our knowledge, this work is the first studying observed labor market impacts of the RGGI.[4] However, a small but growing literature exists that examines how markets have responded to carbon pricing in countries other than the United States. Beyond that, we rely on former studies that have measured the labor market impacts of permit trading programs that targeted other pollutants (like nitrous-oxide), the Clean Air Act of 1970 and 1977, and the amendments made to the Clean Air Act in 1990.

Both the United Kingdom and British Columbia, Canada have implemented carbon-pricing systems, and both have policies been studied for their impacts on labor markets. In the UK the pricing instrument considered is the Climate Change Levy, though they are also part of the larger EU Emissions Trading Scheme. The first microeconometric study on how labor markets have changed following a carbon pricing system is Martin et al. (2014). These authors study the UK carbon pricing policy and find that the policy had a strong negative impact on energy intensity and electricity use, but that there was no statistically significant impacts for employment, revenue, or plant exit. In British Columbia, research has found mixed results for how their revenue neutral carbon policy has affected labor market outcomes. Yamazaki (2017) finds that employment in carbon-intensive and trade-sensitive industries fell, but that employment in the aggregate has not been hurt following the implementation of the revenue neutral tax. In contrast to these findings, Yip (2018) uses worker-level data to determine the effect of carbon pricing on labor markets and finds that the policy increases the unemployment rates of medium- and low-educated males.

Beyond carbon pricing systems, there is a deeper literature on how prior environmental reg-

[4] Casey et al. (2020) use a calibrated model to estimate employment changes and spillover to neighboring, non-carbon-pricing states. We discuss this paper more deeply in the robustness section.

ulation has impacted labor markets. Kahn and Mansur (2013) show that energy-intensive industries concentrate in counties with structurally lower electricity prices, but further find only mixed evidence that pollution-intensive industries locate in counties featuring relatively lax Clean Air Act regulation. Walker (2011) shows that due to the 1990 Clean Air Act Amendments, employment growth (and levels) have changed in affected sectors with estimates suggesting that, in counties that were regulated, the regulated sector was reduced in size by as much as 15 percent. Further, Walker (2013) shows that under the CAA, workers in newly regulated plants experienced, in aggregate, more than $5.4 billion in forgone earnings for the years after the change in policy. These costs are due to nonemployment and lower earnings in future employment. Walker (2013) also emphasizes the needs for longitudinal evidence in analyzing labor market responses to environmental regulation. Curtis (2017) uses a triple difference-in-differences approach to study how manufacturing industries adjusted following the implementation of the nitrous-oxide (NO_x) permit trading program. Curtis (2017) finds that overall employment in the manufacturing sector dropped by 1.3%, with employment in energy-intensive industries falling by 4.8%. Employment declines primarily occur through decreased hiring rates rather than increased separation rates. This has the effect of mitigating the impact on incumbent workers. Curtis (2017) further finds that young workers experienced the largest employment declines, and earnings of newly hired workers fell after the regulation began.

Lastly, we briefly discuss the existing literature on how the RGGI has affected electricity markets and emissions as those conclusions have potential implications for labor markets. The consensus of the literature is that the RGGI has been successful in reducing carbon dioxide emissions, but that carbon leakage is occurring. This leakage primarily occurs through increased power production in neighboring (non-adopting) states at natural gas-fired plants. Kim and Kim (2016), Fell and Maniloff (2018), and Lee and Melstrom (2018) use production data to show that there is policy spillover in neighboring states, and Chan and Morrow

(2019) and Roach and Gittings (2020) use observed emissions levels to assess leakage, though Roach and Gittings (2020) show that the leakage result may be a relic of a biased control group specification. Importantly, Chan and Morrow (2019) and Roach and Gittings (2020) are both able to show that plant-level emissions have changed within the RGGI which indicates that there are localized impacts by generator type. For this reason, we incorporate data from the Quarterly Census of Employment and Wages which has data at the NAICS six digit level to investigate policy impacts that may be occurring at fossil fuel power generators (NAICS 221112). Similar to Roach and Gittings (2020), we also limit the control group states to those belonging to another interconnection and estimate all models with fully clean controls in the appendix.

Our analysis is unique to the literature on the effects of the RGGI because we are the first to measure how labor markets have been impacted. Moreover, this paper adds to the nascent literature on the economic consequences of carbon dioxide taxation by being the first to empirically estimate the labor market effects of carbon dioxide pricing in the United States. Prior work by Metcalf and Stock (2020a) and Metcalf and Stock (2020b) uses variation in taxation rates in the European Union to determine if employment or GDP have changed. These authors find that the there is no effect of carbon taxes on the growth rates of GDP or employment and further state that, “[m]ore importantly, we find no robust evidence of a negative effect of the tax on employment or GDP growth” (Metcalf and Stock (2020a)). The results from our paper yield similar conclusions.

3 Data

Our data for this study span 2001:Q1-2018Q1 in which the RGGI is initially implemented in 2009. To study job flows and labor market impacts of the RGGI, we use local labor market data from two primary sources. First, the Quarterly Workforce Indicators (QWI) produced by the Longitudinal Employer Household Dynamics (LEHD) program at the U.S. Census Bureau provide detailed information on earnings, employment, job flows and worker flows. These data can be disaggregated at very fine levels of detail by industry, geography, and firm and worker characteristics. The second labor market data source is the Quarterly Census of Employment and Wages (QCEW). These data also provide employment and earnings information at fine levels of granulation by geography and industry but do not have information on worker and job flows. The primary benefit of the QCEW for our work is that the data are available down to the six digit NAICS industry classification, whereas the public use version of the QWI only provide information at the four digit level. These data are discussed in greater detail, below. Additionally, we use data from the Energy Information Administration on electricity prices by state and sector and data on the wholesale price of natural gas, the "Henry Hub" price. Program specific data on carbon allowance prices, and quantities of permits sold by state, are publicly available from the RGGI.

Table 1, shows summary statistics for each of our labor market outcome variables. The first column shows these statistics for the entire time-period and all states. The remaining columns separate each outcome by time - before and after the policy start date; region - RGGI adopting states and non-adopting states; and sector - all non-utilities industries and utilities. While the levels of our outcome variables are different in utilities vs non-utilities and RGGI vs non RGGI states, the primary discernible differences in trends are: 1) an increase in earnings for all industries in both RGGI and non RGGI states, 2) a decrease in the hiring rate for non-utilities but not utilities across all states, and 3) a decrease in the worker reallocation rate in non-utilities across all states but no change in the utilities sector. Overall, the summary statistics suggest that the forthcoming null results for the RGGI is not likely an artifact of our choice of specification.

Table 1. Summary Statistics

	Whole Sample	RGGI States				Non-RGGI States			
		Before 2009		After 2009		Before 2009		After 2009	
	All Industries	All Non-utilities	Utilities	All Non-utilities	Utilities	All Non-utilities	Utilities	All Non-utilities	Utilities
Log Employment	14.297	13.925	8.649	13.918	8.541	14.343	9.371	14.398	9.395
	(1.001)	(1.100)	(1.116)	(1.087)	(1.081)	(0.981)	(0.895)	(0.943)	(0.842)
Log Earnings	8.092	8.101	8.668	8.314	8.908	7.931	8.523	8.161	8.779
	(0.199)	(0.202)	(0.206)	(0.194)	(0.211)	(0.144)	(0.167)	(0.138)	(0.167)
Job Creation Rate	0.052	0.055	0.018	0.049	0.019	0.056	0.023	0.049	0.018
	(0.015)	(0.016)	(0.014)	(0.017)	(0.015)	(0.016)	(0.022)	(0.014)	(0.017)
Job Destruction Rate	0.046	0.050	0.018	0.043	0.020	0.050	0.020	0.043	0.017
	(0.011)	(0.010)	(0.012)	(0.009)	(0.016)	(0.012)	(0.018)	(0.010)	(0.016)
Hire Rate	0.190	0.189	0.056	0.156	0.052	0.217	0.059	0.177	0.048
	(0.040)	(0.029)	(0.046)	(0.027)	(0.024)	(0.041)	(0.033)	(0.030)	(0.024)
Separation Rate	0.121	0.120	0.036	0.104	0.037	0.133	0.041	0.115	0.036
	(0.020)	(0.015)	(0.013)	(0.015)	(0.016)	(0.021)	(0.021)	(0.017)	(0.017)
Worker Realloc. Rate	0.311	0.309	0.092	0.259	0.089	0.350	0.100	0.293	0.083
	(0.058)	(0.042)	(0.051)	(0.038)	(0.031)	(0.059)	(0.044)	(0.045)	(0.032)
Job Realloc. Rate	0.098	0.105	0.036	0.092	0.039	0.105	0.043	0.092	0.036
	(0.020)	(0.019)	(0.019)	(0.018)	(0.021)	(0.020)	(0.028)	(0.017)	(0.023)

Notes: Quarterly data from 2001:Q1-2018:Q1.

3.1 The Quarterly Workforce Indicators (QWI)

The microdata underlying the QWI, the LEHD Infrastructure files, are employer-employee matched data constructed from state Unemployment Insurance (UI) records. For our purposes, the QWI data have two primary advantages. First, the QWI measure many variables characterizing labor market dynamics; most importantly on the movements of workers into and out of firms as well as job creation, job destruction and job reallocation. Second, the data can be disaggregated by detailed geography and industry. The measurement of employment characteristics by geography and industry allow us to study the interaction between the RGGI's carbon caps and employment reallocation.

The QWI data used in this paper covers all 50 states for the period 2000:Q1–2018:Q1.[5] Our primary analyses use data at the NAICS sector level and data disaggregated by NAICS 4-digit industry codes. We use the following QWI variables measured at state-industry-quarter detail: employment, new hires, separations, jobs created, jobs destroyed and total monthly earnings. While we measure employment and earnings in logarithm, worker flows and job flows are expressed as rates by dividing the numerator by average employment in the current

[5]We used the R2019Q1 version of the public use Quarterly Workforce Indicators. The raw data are available for download from `https://lehd.ces.census.gov/data/`.

and previous quarter. For example, the new hire rate in an industry is given by:

$$HireRate_{st} = \frac{NewHires_{st}}{(Emp_{st} + Emp_{s,t-1})/2}$$

The worker reallocation rate measures the intensity at which workers move into and out of jobs. The job reallocation rate measures the frequency at which jobs are reallocated across firms and establishments. We compute the worker reallocation rate and job reallocation rate using standard methodology:

$$WorkerReallocationRate_{st} = \frac{NewHires_{st} + Separations_{st}}{(Emp_{st} + Emp_{s,t-1})/2}$$

$$JobReallocationRate_{st} = \frac{JobsCreated_{st} + JobsDetroyed_{st}}{(Emp_{st} + Emp_{s,t-1})/2}$$

The QWI data also do not currently include reliable or consistent information on public-sector employment or self-employment. We restrict our analysis to jobs where the employer reports being privately owned. Like the QCEW, the QWI contain measures of total labor market earnings, but do not separately report wage rates or hours of work. We have no measure of labor utilization at the intensive margin. Therefore, our analysis is restricted to the extensive margin of employment and employment dynamics.

3.2 Quarterly Census of Employment and Wages

While the QWI is a data product of the U.S. Census Bureau, the QCEW data are published by the Bureau of Labor Statistics. However, the primary underlying microdata to produce both data products is the same. The QWI and QCEW both rely on unemployment insurance records that are provided to the agencies by each state. Each data source has information on employment and earnings, but for our purposes, the primary advantage of the QCEW is the greater level of industry detail in the public use data.

The QCEW provides data by six digit NAICS industry classifications while the public use version of QWI provides data only down to the four digit NAICS industry level of detail. Since we are studying the electricity industry, this additional level of disaggregation is meaningful. The Utilities sector is classified as NAICS 22 (2 digit). For the utilities sector, there is no further disaggregation at the three digit level and all utilities establishments fall within NAICS 221 subsector. There are three industry groups at the NAICS 4 digit level within Utilities: Electric Power Generation, Transmission and Distribution (2211), Natural Gas Distribution (2212), and Water, Sewage and Other Systmes (2213).

Within these three industry groups, which are all covered by the QWI, the RGGI should have a direct effect on Electric Power Generation, Transmission and Distribution (2211). However, this classification is too broad and covers many establishments that will not be affected or will be minimally affected. Thus, the five digit industries within NAICS 2211 are Electric Power Generation (22111) which is relevant for our analysis and Electric Power Transmission, Control and Distribution (22112) which is less relevant. At the six digit level, NAICS classifies eight industries within Power Generation.[6] When utilizing the QCEW we focus on the Fossil Fuels (221112) generating sector, the Electric Power Generation (22111) and Electric Power Transmission, Control and Distribution (22112) classifications. The downside to this granular of an industry classification is that only employment and earnings are available in the QCEW with no job flows or labor market dynamics.

[6]Hydroelectric (221111), Fossil Fuels (221112), Nuclear (221113), Solar (221114), Wind (221115), Geothermal (221116), Biomass (22117), and Other (221118).

3.3 Energy Information Administration

All energy market data comes from publicly available data at the Energy Information Administration (EIA). We make use of quarterly averages of the wholesale price of natural gas, the Henry Hub price, as well as state-specific electricity prices. The EIA collects three separate electricity price series: residential, industrial, and commercial. We merge electricity prices with associated industries as defined by the EIA. The industrial sector encompasses the following types of activity: manufacturing (NAICS codes 31-33); agriculture, forestry, and hunting (NAICS code 11); mining, including oil and gas extraction (NAICS code 21); natural gas distribution (NAICS code 2212); and construction (NAICS code 23). The commercial sector is "[a]n energy-consuming sector that consists of service-providing facilities and equipment of: businesses; Federal, State, and local governments; and other private and public organizations, such as religious, social, or fraternal groups. The commercial sector includes institutional living quarters. It also includes sewage treatment facilities." (EIA, 2019) We use these same industry categories to compare RGGI policy changes seen in the electric power sector with possible spillover effects in the EIA-defined Industrial and Commercial sectors in Tables 2, 3, and 6.

4 Empirical Strategy

To measure the impact of the RGGI on labor market outcomes and dynamics we use a standard difference-in-differences panel data framework. Within our analysis, we use two policy treatment periods which capture the introduction of the carbon permit trading system as well as a subsequent tightening of the carbon cap. The treatment group pertaining to the RGGI is easily identified because treatment is sharply defined along state lines. Hence, states outside of the RGGI are used as a 'treatment-free' comparison group subject to the same global factors that both treated and untreated units face (e.g. changes in interest rates and commodity markets). The first RGGI carbon permit auction occurred on September 10, 2008 for permits needed for the implementation date of January 1, 2009. Therefore, the initial period of the carbon trading policy begins in 2009:Q1, which we use as the first 'treatment' period. We are also able to use variation in the intensity of treatment as the cap on emissions was lowered from the original carbon cap in 2014. This second policy intervention serves as our second treatment period. Our benchmark specification is shown in equation (1).

$$\begin{aligned} y_{st} &= \beta_1 RGGI_s + \beta_2 Begin_t + \beta_3 CapLower_t \\ &\quad + \theta_1 RGGI_s * Begin_t + \theta_2 RGGI_s * CapLower_t \\ &\quad + \mu_s + \lambda_t + t\mu_s + \pi_s Recession + \varepsilon_{st} \end{aligned} \tag{1}$$

In this specification, note that while the panel is composed of state-period observations, for each model the data are subset by industry and estimated separately. The dependent variable y_{st} is the labor market outcome of interest for a particular industry in state s and quarter t. The binary indicator $RGGI_s$ is equal to one for the 10 states within the initiative.[7] Both $Begin_t$ and $CapLower_t$ are policy treatment indicators. $Begin_t$ marks the introduction of the RGGI policy in 2009:Q1, and is set equal to one from 2009:Q1 through 2013:Q4 when the emissions cap reduction occurs. The indicator $CapLower_t$ is set equal to one starting in 2014:Q1. Both θ_1 and θ_2 are our major parameters of interest as these capture the treatment effect of the RGGI policy and subsequent tightening. Including both treatment variables allows us to measure how the RGGI policy has impacted the labor market non-linearly over

[7] We adjust for New Jersey's exit from the RGGI in 2012 so that RGGI is coded as zero for New Jersey post 2012.

time through the initial implementation and tightening. We also include the following fixed effects: state fixed effects (μ_s), time period fixed effects by year and quarter (λ_t), state–specific linear time trends ($t\mu_s$), and state-specific recession effects ($\pi_s Recession$).[8] The 2008-2009 financial crisis resulted in a recession that impacted all geographical markets, but had a differential effect across labor markets depending on economic characteristics specific to each state. All standard errors are clustered by state.

5 Main Results

We begin by measuring how the implementation and tightening of the carbon cap has affected industries in the RGGI-area for the eight outcome variables of interest in the QWI for NAICS industries in aggregate, in the electric power sector, and by category. The primary effect of the RGGI should be on the utilities industry, as this is the industry that is directly regulated and bears the statutory incidence of new carbon expenses. Here, we determine how these policies have affected labor market dynamics within industries of the NAICS electric power sector (NAICS 2211) as well as an average estimate for spillover effects in all industries and in industries categorized as Industrial or Commercial by the Energy Information Administration (EIA).[9,10]

Tables 2 and 3 show the difference-in-differences estimates for each treatment period for each grouping of industries. The unit of observation for the latter three columns is a NAICS 4-digit

[8] National recessions are identified from the NBER. State-specific recession effects are then simply the interaction of state dummies and the recession indicator.

[9] The industrial sector encompasses the following types of activity: "manufacturing (NAICS codes 31-33); agriculture, forestry, and hunting (NAICS code 11); mining, including oil and gas extraction (NAICS code 21); natural gas distribution (NAICS code 2212); and construction (NAICS code 23)." (EIA, 2019)

[10] The commercial sector is "[a]n energy-consuming sector that consists of service-providing facilities and equipment of: businesses; Federal, State, and local governments; and other private and public organizations, such as religious, social, or fraternal groups. The commercial sector includes institutional living quarters. It also includes sewage treatment facilities." (EIA, 2019)

Table 2. QWI, Reduced Form Results

Dep. Variable	All Industries	Electric Power	Industrial	Commercial
ln Employment				
RGGI · Begin	0.011	0.013	-0.047	0.007
	(0.009)	(0.028)	(0.029)	(0.008)
RGGI · Cap Lower	0.012	0.030	0.013	0.008
	(0.012)	(0.048)	(0.032)	(0.012)
ln Earnings				
RGGI · Begin	-0.003	0.011	0.002	-0.002
	(0.005)	(0.020)	(0.009)	(0.004)
RGGI · Cap Lower	-0.003	0.019	0.024	0.001
	(0.010)	(0.033)	(0.017)	(0.006)
Job Creation Rate				
RGGI · Begin	0.003*	0.001	0.011***	0.003**
	(0.002)	(0.005)	(0.003)	(0.001)
RGGI · Cap Lower	0.008**	0.005	0.017***	0.005***
	(0.004)	(0.006)	(0.005)	(0.001)
Job Destruction Rate				
RGGI · Begin	-0.000	-0.001	-0.014***	-0.003***
	(0.002)	(0.005)	(0.004)	(0.001)
RGGI · Cap Lower	0.002	0.007	-0.029***	-0.005***
	(0.004)	(0.005)	(0.008)	(0.002)
State FE	Y	Y	Y	Y
Industry FE	N	N	Y	Y
Year FE	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y
State Recessions	Y	Y	Y	Y
State Trends	Y	Y	N	N
State-Industry Trends	N	N	Y	Y

Notes: Unit of observation is state-quarter in the first two columns, and state-industry-quarter in the latter two columns; Robust standard errors clustered by state (first two columns) state-industry (latter two columns); *,**,*** denote statistical significance at the 10%, 5%, and 1% level, respectively.

sector at a quarterly interval.[11] Both tables are broken down into four panels. Each panel identifies the dependent variable in the model (For Table 2: ln Employment, ln Earnings, Job Creation Rate, Job Destruction Rate). Column headings in columns 2 to 6 identify the industry group for which the model is estimated. The cells pertaining to each model display the parameter estimates for $RGGI_s * Begin_t$ and $RGGI_s * CapLower_t$ and clustered standard errors are in parentheses.

In Table 2, we find no evidence that the passing of the RGGI carbon program, nor the eventual tightening of the carbon cap, affected employment or earnings in any industry. That is, relative to non-RGGI areas, there is no evidence of job loss or an effect on earnings due to the carbon trading program. This remains true when we look specifically to the utilities sector and sub-industries.

Table 2 also suggests that the RGGI had no effect on job creation on industries within the utilities sector but did have a small positive effect on job creation in Industrial and Commercial sectors. The parameter estimates by treatment period are 0.003 and 0.005 in the Commercial sector which are small in magnitude, though the mean job creation rate in Table 1 is 0.052, so the marginal effect suggests job creation rose by 5.8-9.6% relative to the mean. We also see a decline in the job destruction rate following RGGI implementation for both Industrial and Commercial sectors. Again, this is relative to same-sector NAICS industries outside of the RGGI.

In Table 3, among the four labor market outcomes we see that the hire rate, separation rate, and the worker reallocation rate were all statistically different in the RGGI-region relative to industries in treatment-free comparison states. This is true at the widest resolution of 'All Industries,' and remains true when we look specifically at the Industrial sector and Commercial sector. We do not see any statistically discernible effect of the RGGI on job flows in the most narrow resolution, 'Electric Power.'

[11] We use data aggregated by state for the 'All Industries' category.

Table 3. QWI Reduced Form Results

Dep. Variable	All Industries	Electric Power	Industrial	Commercial
Hire Rate				
RGGI · Begin	0.019***	0.009	0.026***	0.012***
	(0.003)	(0.016)	(0.005)	(0.002)
RGGI · Cap Lower	0.024***	0.025	0.040***	0.012***
	(0.005)	(0.027)	(0.008)	(0.003)
Separation Rate				
RGGI · Begin	0.005**	0.002	-0.008*	0.001
	(0.002)	(0.005)	(0.004)	(0.002)
RGGI · Cap Lower	0.007**	0.009*	-0.019**	-0.001
	(0.003)	(0.006)	(0.008)	(0.002)
Worker Realloc. Rate				
RGGI · Begin	0.024***	0.011	0.021***	0.013***
	(0.005)	(0.018)	(0.005)	(0.003)
RGGI · Cap Lower	0.032***	0.034	0.025**	0.011***
	(0.008)	(0.028)	(0.010)	(0.004)
Job Realloc. Rate				
RGGI · Begin	0.003	0.000	-0.004	-0.001
	(0.003)	(0.009)	(0.005)	(0.001)
RGGI · Cap Lower	0.010	0.011	-0.012	-0.000
	(0.007)	(0.010)	(0.008)	(0.002)
State FE	Y	Y	Y	Y
Industry FE	N	N	Y	Y
Year FE	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y
State Recessions	Y	Y	Y	Y
State Trends	Y	Y	N	N
State-Industry Trends	N	N	Y	Y

Notes: Unit of observation is state-quarter in the first two columns, and state-industry-quarter in the latter two columns; Robust standard errors clustered by state (first two columns) state-industry (latter two columns); *,**,*** denote statistical significance at the 10%, 5%, and 1% level, respectively.

A simultaneous increase in both hiring and separation rates is consistent with a strong labor market, which in turn increases the worker reallocation rate. At first glance, it may not be clear why the implementation of the RGGI and tightening of the cap would improve labor market conditions in non-utilities. In fact, this may appear as a failed placebo test. However, the RGGI has extracted more than \$3.7 Billion overall in auction revenues in just over 10 years, which in turn distributed back to states an average of about \$370 Million per state. Broadly, these RGGI permit revenues have been used to fund activities like energy efficiency audits and improvements, renewable energy development, and low-carbon city services. From a revenue standpoint, much of that money has been redirected outside the utilities sector. So, it could be that the positive aggregate and non-utilities results we see here are the consequence of those investments in RGGI funds combined with a change in market incentives due to the policy.

Alternatively, recall that implementation of the RGGI coincided almost simultaneously with the recovery from the Financial Crisis. While our model includes parameters for unobservables that should account for these economic fluctuations (common time effects, state-specific recessionary effects, and state-specific trends), there may be more unobservable aspects that are correlated the recovery, RGGI timing, and industry characteristics that our model is not addressing. It is possible that what we see in Table 3 is that, while the RGGI did not have wide-spread destructive effects on the Utilities sector for hiring and separations (in turn worker reallocation), the RGGI may have muted the recovery in the utilities sector within RGGI states. This is one of the primary reasons we adopt a differences-in-differences-in-differences approach in the robustness section of the paper. We must also consider the fact that the RGGI policy only really impacts non-regulated sectors like those in the Industrial or Commercial categories through the policy's effect on the price of electricity. This is why we also use an instrumental variables model in the robustness section to account for endogenous electricity price effects. Still, when we account for carbon dioxide price transmission we uncover statistically similar results.

Next, we refine our scope further to the NAICS 6 industry level using data from the QCEW. We highlight more refined cuts of the electric power generation and distribution sector (NAICS 2211) by focusing on: the Fossil Fuel Generation sector (NAICS 221112), Electric Bulk Power Transmission and Control (NAICS 221121) and Electric Power Distribution (NAICS 221122). For context, the Electric Bulk Power Transmission and Control sub-sector includes establishments primarily engaged in operating electric power transmission systems by regulating voltages and monitoring the transmission of electricity from the generating source to distribution centers or other electric utilities. The Electric Power Distribution sub-sector includes firms that mostly engage in either (1) operating electric power distribution systems (i.e., consisting of lines, poles, meters, and wiring) or (2) operating as electric power brokers or agents that arrange the sale of electricity via power distribution systems operated by others. Table 4 presents the treatment effect estimates for both policy changes for these three sectors for the following outcome variables: employment, weekly earnings, and the total number of establishments.

In Table 4, the results are perhaps surprisingly muted for the Fossil Fuel Generation industry and not consistent elsewhere. The fossil fuel electricity generation industry should clearly be the industry most impacted by the RGGI. Parameter estimates in this industry for both employment and earnings are all negative but imprecisely estimated. We find no effect on employment for either of the other two six digit industries either. We do see that the initial implementation of the RGGI has a meaningfully positive effect on earnings for electricity power transmission and control, but not in distribution. Similarly, the number of establishments has increased in the electric power distribution sub-sector while they have declined in the bulk power transmission sub-sector. This, perhaps, could be a result of recycled permit revenues, though we are not able to determine this conclusively with our data. The conflicting positive effects of the RGGI in the last two columns, combined with the null

Table 4. QCEW, NAICS 6

Dep. Variable	Fossil Fuel Generation (221112)	Electric Bulk Power Trans. & Control (221121)	Electric Power Distribution (221122)
ln Employment			
RGGI · Begin	-0.097	-0.756	-0.045
	(0.241)	(0.648)	(0.276)
RGGI · Cap Lower	0.021	-0.831	-0.000
	(0.306)	(0.873)	(0.492)
ln Weekly Earnings			
RGGI · Begin	-0.038	0.174***	-0.005
	(0.056)	(0.042)	(0.030)
RGGI · Cap Lower	-0.080	0.038	0.056
	(0.095)	(0.340)	(0.060)
ln # of Establishments			
RGGI · Begin	0.173	-0.285*	0.484**
	(0.166)	(0.144)	(0.213)
RGGI · Cap Lower	0.353	-0.157	1.123**
	(0.357)	(0.311)	(0.427)
Year FE	Y	Y	Y
State FE	Y	Y	Y
Quarter FE	Y	Y	Y
State Recessions	Y	Y	Y
State Trends	Y	Y	Y

Notes: Robust standard errors clustered by state; *,**,*** denote statistical significance at the 10%, 5%, and 1% level, respectively.

effect on fossil fuels, are somewhat perplexing since the RGGI is targeting inputs in electricity production and not delivery. When estimating models for all other 6-digit industries within Utilities Sector 22, no effect of the RGGI can be found. In summary, the marginally significant results presented in this table should be considered with caution because they are associated with wider standard errors and less precision than the estimates at the 4-digit NAICS classification.

6 Alternative Specifications

6.1 First-order Effects and Carbon-price Transmission

The RGGI policy should affect industries within the utilities sectors differently based on the carbon content of the input fuel source.[12] Beyond this, the concern among some policymakers is the transmission of new costs (carbon permit expenses) into electricity prices that may cause spillover labor market effects in industrial or commercial sectors. Because elec-

[12] e.g. at the 6-digit NAICS sector-level we might expect employment at fossil fuel electric power generation to be negatively impacted relative to other industries, though the prior analysis shows that this is not the case

tricity is an input to production, we seek to determine if the RGGI caused higher electricity costs, and if it has, how have these costs affected labor demand? There are two main channels through which this may occur: lower product demand because these costs have been transmitted into the final price of the good (and hence lower derived demand for labor), or through input substitution to offset increased production costs (labor as a gross complement or gross substitute with electricity).

The reason that the carbon cap allowance was adjusted lower in 2014 was that an over-supply of natural gas occurred following the advent of new oil and gas production techniques.[13] This shock to natural gas supply brought wholesale prices down from the June 2008 high of $12.69 per million BTU to under $3.00 per million BTU in September of 2009.[14] This drop in prices lead to interfuel substitution away from coal which releases more CO_2 per unit of heat than natural gas. Indeed, much of the original emissions reductions goals were rendered moot by unexpected market forces and the cap tightening was necessary for the policy to be 'binding.'

Of particular importance to our study is the fact that natural gas-fired plants are often the price-setters in electricity markets because they are the marginal plant that is called on in merit-order dispatch of electricity. Thus, the settlement price for most hours of electricity generation is dependent on the wholesale prices of natural gas. Because this over-supply of natural gas occurred nearly concurrently with the RGGI policy introduction, there are two conflicting forces at play that stand to impact electricity prices which we must account for: natural gas abundance puts downward pressure on electricity prices while carbon expenses stand to push prices higher. We identify our model using contemporaneous and lagged values of the the wholesale price of natural gas, the Henry Hub price. Our identification strategy is

[13] hydraulic fracturing or "fracking"

[14] In some shale regions there have actually been negative upstream prices due to lagging pipeline infrastructure, and in many locations natural gas is burned off or 'flared' on site because it is not economically viable to transport.

further aided by the inclusion of state fixed effects which capture unobserved heterogeneity in pipeline infrastructure and electricity market regulation, and year and quarter fixed effects which capture seasonal variation in pricing.[15] The first stage of our instrumental variables model is given by the following equation:

$$\begin{aligned} ElectricityPrice_{st} &= \gamma_0 + \gamma_1 CarbonExpense_{st} + \sum_{j=0}^{3} \gamma_{2+j} HenryHub_{t-j} \\ &+\beta_1 RGGI_s + \beta_2 Begin_t + \beta_2 CapLower_t \\ &+\theta_1 RGGI_s * Begin_t + \theta_2 RGGI_s * CapLower_t \\ &+\mu_s + \lambda_t + \upsilon_{st} \end{aligned} \tag{2}$$

Here we control for variation in the wholesale price of natural gas contemporaneously, and up to 3 quarters in the past ($HenryHub_{t-j}$); We also control for state specific carbon expenditures ($CarbonExpense_{st}$) each quarter, which is the number of permits purchased multiplied by the settlement price of permits in that quarter. We are also able to account for and determine the treatment effect of the RGGI passing on electricity prices using the same difference-in-differences design with two treatment dates.

The electricity price data used for this first stage regression, $ElectricityPrice_{st}$ is from the EIA data on state electricity profiles. In this data there are multiple price series that average the prices faced by the industrial sector, the commercial sector, and the residential sector in each state and quarter. For our analyses, we use data on industrial sector electricity prices and commercial sector electricity prices which are aggregated by NAICS industry groups

[15]For the parameters on the Henry Hub price to be identified, we cannot include a time period effect for every quarter of the data in this model. Hence, the year effects and quarter effects (now common seasonality across years) are estimated separately in this case.

Table 5. First-Stage Price Effects

	Industrial Sector	Commercial Sector
HenryHub	-0.111	0.449
	(0.250)	(0.296)
$HenryHub_{t-1}$	2.158***	1.909**
	(0.800)	(0.866)
$HenryHub_{t-2}$	-2.132***	-0.762
	(0.476)	(0.586)
$HenryHub_{t-3}$	0.768***	0.571***
	(0.138)	(0.148)
Carbon Expense	-0.004*	-0.001
	(0.002)	(0.001)
RGGI · Begin	0.223	0.087
	(0.414)	(0.393)
RGGI · Cap Lower	-0.052	-0.200
	(0.452)	(0.458)
Year FE	Y	Y
Quarter FE	Y	Y
State FE	Y	Y
R^2	0.874	0.892

Notes: Standard errors clustered by state; *,**,*** denote statistical significance at the 10%, 5%, and 1% level, respectively.

according to EIA definitions.[16,17]

For the second stage, we augment equation (1) by adding predicted values for electricity prices from the first stage estimation in equation (2).[18] This empirical strategy modifies the interpretation of our differences-in-differences model so that we estimate the effect of the RGGI holding constant electricity prices which would otherwise be endogenous. The idea is that our estimates of the effect of the RGGI are now holding constant substitution and scale effects associated with electricity prices changes that may have occurred with the implementation of the RGGI.

Table 5 presents results from the first stage of the IV model. As expected, the wholesale Henry Hub prices (the instruments) are a strong predictor of industrial and commercial

[16]The industrial sector encompasses the following types of activity: "manufacturing (NAICS codes 31-33); agriculture, forestry, and hunting (NAICS code 11); mining, including oil and gas extraction (NAICS code 21); natural gas distribution (NAICS code 2212); and construction (NAICS code 23)." (EIA, 2019)

[17]The commercial sector is "[a]n energy-consuming sector that consists of service-providing facilities and equipment of: businesses; Federal, State, and local governments; and other private and public organizations, such as religious, social, or fraternal groups. The commercial sector includes institutional living quarters. It also includes sewage treatment facilities." (EIA, 2019)

[18]For both price series the first stage F statistic greatly exceeds 104.7 (Lee et al. (2020))

electricity prices. However, neither the implementation of the RGGI nor the lowering of the cap have an effect on industrial or commercial energy prices. This result is surprising but not wholly unexpected given the low initial carbon permit price. This may also help explain the largely null effects on employment and earnings we have observed so far.

In Table 6 we present results from the full IV difference-in-differences model for all labor market dynamics. In these models, we provide three separate specifications: using observations from all industries, using only NAICS sectors marked as 'industrial' by the EIA, and using NAICS sectors marked as 'commercial' by the EIA.[19]

As before, the RGGI does not appear to have consistent statistical effect on employment, earnings or job reallocation. There is is some evidence that employment has decreased in the industrial sector following the policy implementation although the parameter is not precisely estimated. Positive effects remain for the hire rate and worker reallocation but the positive effect on separations is largely wiped out. Furthermore, we find that there is a decrease in the job destruction rate across industries in the industrial sector that was not apparent in Table 2. As a collection, these results suggest potential positive spillovers of the RGGI on the labor market, or at a minimum a non-negative impact on the labor market.

6.2 Control Group Selection

The average treatment effect of the RGGI carbon market on labor outcomes is defined as the change in the RGGI area relative to the change over time in non-adopting states. These non-adopting states serve as the 'potential outcome' that would be witnessed in the RGGI absent the policy. Originally, our analysis used the rest of the United states as a treatment-free comparison group. A consistent finding in the early literature discussing how the RGGI carbon market has effected carbon dioxide emissions is that emissions are

[19] In the 'all industries' specification the electricity price is still specific by EIA sector

Table 6. Carbon Price Transmission IV Model

	ln Employment			ln Earnings			Job Creation Rate			Job Destruction Rate		
	All Inds	Industrial	Commercial	All Inds	Industrial	Commercial	All Inds	Industrial	Commercial	All Inds	Industrial	Commercial
RGGI · Begin	-0.007	-0.049*	0.006	0.000	0.001	-0.000	0.005***	0.011***	0.003**	-0.005***	-0.012***	-0.003**
	(0.009)	(0.028)	(0.008)	(0.004)	(0.009)	(0.004)	(0.001)	(0.003)	(0.001)	(0.001)	(0.004)	(0.001)
RGGI · Cap Lower	-0.000	-0.008	0.010	0.010	0.027	0.009	0.008***	0.017***	0.005**	-0.010***	-0.024***	-0.002
	(0.012)	(0.029)	(0.012)	(0.006)	(0.018)	(0.006)	(0.002)	(0.005)	(0.002)	(0.003)	(0.008)	(0.002)
Electricity Price	-0.013	-0.003	0.011***	-0.001	0.010	0.012***	-0.002	0.002	-0.003***	-0.004*	0.000	0.005***
	(0.016)	(0.017)	(0.002)	(0.008)	(0.007)	(0.003)	(0.004)	(0.002)	(0.001)	(0.002)	(0.003)	(0.001)
R^2	0.997	0.996	0.998	0.980	0.965	0.982	0.515	0.588	0.478	0.547	0.569	0.585
Obs.	63353	15825	47528	63362	15834	47528	63309	15811	47498	63309	15811	47498
	Hire Rate			Separation Rate			Worker Reallocation Rate			Job Reallocation Rate		
	All Inds	Industrial	Commercial	All Inds	Industrial	Commercial	All Inds	Industrial	Commercial	All Inds	Industrial	Commercial
RGGI · Begin	0.018***	0.030***	0.014***	0.001	-0.005	0.003	0.019***	0.026***	0.017***	0.000	-0.001	0.001
	(0.003)	(0.005)	(0.003)	(0.002)	(0.005)	(0.002)	(0.003)	(0.007)	(0.004)	(0.002)	(0.005)	(0.001)
RGGI · Cap Lower	0.024***	0.046***	0.017***	-0.002	-0.012	0.005**	0.023***	0.037***	0.022***	-0.002	-0.007	0.003
	(0.004)	(0.009)	(0.003)	(0.003)	(0.008)	(0.002)	(0.005)	(0.012)	(0.004)	(0.003)	(0.010)	(0.002)
Electricity Price	0.000	0.001	0.003*	-0.001	0.000	0.008***	-0.001	0.002	0.010***	-0.006	0.002	0.002**
	(0.006)	(0.004)	(0.001)	(0.003)	(0.003)	(0.001)	(0.007)	(0.005)	(0.002)	(0.004)	(0.003)	(0.001)
R^2	0.845	0.797	0.881	0.790	0.712	0.859	0.916	0.876	0.939	0.806	0.844	0.772
Obs.	63295	15797	47498	63309	15811	47498	63295	15797	47498	63309	15811	47498

Notes: Dependent variable shown in column headers; All models include the following: year, quarter, and state-industry fixed effects, state-specific recessions, state-industry trends; Standard errors clustered by state-industry; *,**,*** denote statistical significance at the 10%, 5%, and 1% level, respectively.

"leaking" to neighboring states. The hypothesis is that this policy spillover effect occurs because electricity demand is relatively inelastic, and electricity production in the RGGI region is being replaced by new natural gas production from nearby states that are not signatories to the RGGI. Indeed, Kim and Kim (2016), Fell and Maniloff (2018), Lee and Melstrom (2018), and Chan and Morrow (2019) all show that electricity production and emissions have increased at natural-gas-burning facilities outside of the RGGI region: in the 'leaker' region of Pennsylvania and Ohio (Fell and Maniloff (2018)) as well as in states that are part of PJM balancing authority but are not signatories to the RGGI (Chan and Morrow (2019)). However, Roach and Gittings (2020) draw the conclusion that the parallel trends assumption fails for these spillover estimates and, moreover, policy spillover into control group states is intrinsically problematic with how difference-in-differences analyses determine the size of a treatment effect.[20] These authors advocate the use of "clean" controls that are comprised of observations outside of the eastern interconnection. This is because

[20]When we separately accounted for states that are part of the PJM or Leaker territories we did not find any statistically discernible differences in the RGGI region compared to the estimates presented in Tables 2 and 3, nor did we find evidence of spillover into labor outcomes in these regions. These models are not presented here for the sake of brevity but are available on request.

electricity supply and demand is balanced across the eastern interconnection that includes all RGGI-adopting states and many non-adopting states. The mere potential of spillover or tainted (non-stable) control observations motivates the need for a fully clean control group in which policy spillover cannot occur.

For this robustness check we use a slate of control group states in which policy spillover physically cannot occur because of engineering constraints as in Roach and Gittings (2020). The "clean" control group is comprised of observations that lie within the western interconnection or Texas, both of which do not share an electricity grid with RGGI-adopting states. We re-estimate the model shown in Tables (2) and (3) using only clean controls and present estimates in the appendix. Our results here reinforce our prior findings of increased labor market churn. We see that job creation, destruction, and reallocation rates are all greater due to the RGGI. Interestingly, we now find that employment and earnings are now higher following the beginning and cap lowering of the RGGI permit trading system.

6.3 Event-study Analysis

The differences-in-differences model requires the familiar parallel trends assumption between treated units and controls. That is, both the control group and treated group should follow similar trajectories before the policy change, and we must reasonably expect that treated groups would continue to follow this trajectory in the absence of the policy treatment.[21] In this subsection, we will test that assumption by estimating the RGGI treatment effects for each time period in the data using 2008:Q4 as the based period.[22]

Our estimating equation now becomes the following:

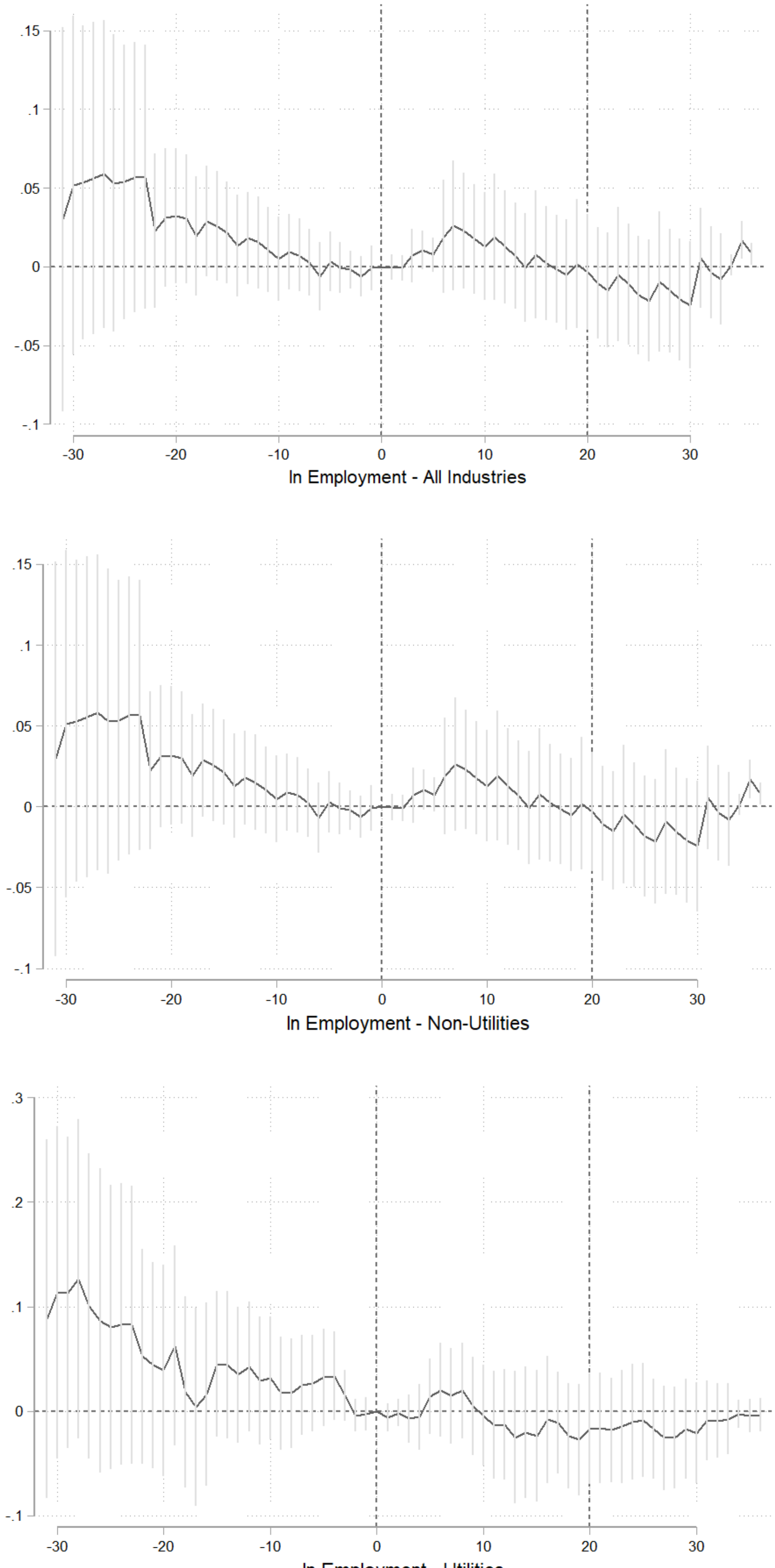
[21]No concurrent policy changes that would produce a similar result or bias outcomes one way or another.
[22]The triple DDD model that follows is yet another check on this assumption.

$$y_{st} = \beta_0 + \sum_{\substack{t=t_0 \\ t \neq 2008Q4}}^{t} \Big[\theta_t RGGI * I(YearQuarter = t)\Big] + \mu_s + \lambda_t + t * \mu_s + \varepsilon_{st} \quad (3)$$

The previous models we estimated combined the post-RGGI period into two effects: the implementation period and the cap tightening period. This model is more dynamic as it estimates the effect of the RGGI in each post period separately. Since the caps evolved as a step function post 2009, this exercise should distinguish the effect for each time the cap is lowered. Furthermore, here we estimate the effect of the RGGI in the pre-2009 period in which we should find no effect of the RGGI if the common trends assumption holds. y_{st} is again one of our eight outcome variables. As before, the data are subset by industry group before estimating: using all the data (All Industries), Non-utilities industries, and Utilities industries (NAICS sector 22).

In Figure 2 we provide event-study plots for the employment outcome and all three industry groups. The figures plot the estimated parameters (θ_t) and standard errors for all quarters preceding and following the implementation of the RGGI cap and trade policy. Dotted vertical lines mark the start of the carbon permit policy in 2009 and the 2014 tightening of the carbon cap. The results of this analysis confirm the prior findings for employment as an outcome (no RGGI effect on employment). Also, the estimated effects of the RGGI in the pre-2009 period are statistically zero supporting the common trends assumption of the differences-in-differences model. Event-study images for all outcome variables are available in the appendix. For almost all outcomes and industries, all estimated parameters (θ_t) are statistically zero with no clear trend before or after the implementation of the RGGI. One exception is the hiring rate and worker reallocation rate, which sees a notable shift higher in the post period for Non-utilities (and all industries). This is not the case for the Utilities sector.

Figure 2: Event-Study Model



6.4 Utilities Sector: Differences-in-Difference-in-Differences

As a final robustness check, we leverage the richness of our data to dissect the changes in our outcome variables relative to targeted and non-targeted industries across states by estimating a differences-in-difference-in-differences (DDD) model. While our earlier work was able to account for differential trends in outcomes between RGGI states and non RGGI states, those analyses were industry or industry group specific. One possibility is that there remained unobservable aspects specific to industries that were correlated with the implementation of the RGGI and the outcomes. As mentioned earlier, the implementation of the RGGI coincided with the beginning of the recovery from the Financial Crisis. For example, if utilities and non-utilities recovered non-uniformly, and this non-uniform recovery differed across RGGI and non-RGGI states, our earlier results may be misleading.

The DDD model will allow us to compare differences in outcomes between utilities and non-utilties in RGGI states, to differences in outcomes between utilities and non-utilities in non RGGI states. To do so, we will extract all state-NAICS sector level data from the QWI. Rather than estimating the model sector by sector, we stack the sectors together to create a richer panel data set so that our unit of observation becomes a state-industry-time period. In addition to being able to identify the DDD parameter, we are now able to include state-industry fixed effects and state-industry specific time trends rather than only state fixed effects and state-specific time trends. Otherwise, the specification remains similar to Equation (1). The results of this model should alleviate the concerns mentioned above regarding unobservables correlated with the implementation of the RGGI and the outcomes but my differ across industries.

Our estimating equation is shown below.

$$
\begin{aligned}
y_{ist} \;=\;& \beta_0 + \beta_1 RGGI_s + \beta_2 Begin_t + \beta_2 CapLower_t + \beta_3 Utilities_i \qquad (4) \\
&+\beta_4 RGGI_s * Begin_t + \beta_5 RGGI_s * CapLower_t + \beta_6 RGGI_s * Utilities_i \\
&+\beta_7 Utilities_i * Begin_t + \beta_8 Utilities_i * CapLower_t \\
&+\theta_1 RGGI_s * Begin_t * Utilities_i + \theta_2 RGGI_s * CapLower_t * Utilities_i \\
&+\mu_{is} + \lambda_t + t * \mu_{is} + \pi_s Recession + \varepsilon_{st}
\end{aligned}
$$

Our parameters of interest in Equation (4) are θ_1 and θ_2 which give us the estimated treatment effects for the RGGI implementation period and when the cap was lowered. The results are presented in Table 7.

We again find no effect of the RGGI on employment or earnings. There is also no effect of the RGGI on the job creation rate, hiring rate or worker reallocation rate. However, this model suggests that there are large increases in job destruction and separations in the utilities sector as a result of the RGGI. From Table 1, for Utilities in RGGI States prior to 2009, the mean job destruction rate is 0.018 and the mean job separation rate is 0.036. Adding the two coefficients for job destruction (0.010 + 0.019) yields a total effect of 0.029. This translates to a 161% increase in job destruction over the mean. Adding the two coefficients for separations (0.007 + 0.015) yields a total effect of 0.022, which translates to a 61% increase in separations over the mean. While we cannot distinguish layoffs in the separations data, these results are consistent the large increase in the rate of job destruction in the utilities sector. Note we also see that the job reallocation rate increased as well. Taken together, the increased job destruction and higher job reallocation but no change in employment, suggests that the destroyed jobs were likely reallocated from firms hurt by the RGGI to firms who were able to absorb those workers. This result truly highlights the main results of our paper and the overall impact of the RGGI. The RGGI implemented a new carbon dioxide pricing scheme

Table 7. Triple Difference Model

	ln Employment	ln Earnings	Job Creation Rate	Job Destruction Rate
RGGI · Begin· Utilities Sector	0.008	-0.000	0.003	0.010***
	(0.018)	(0.014)	(0.002)	(0.003)
RGGI · Cap Lower · Utilities Sector	0.002	-0.003	0.004	0.019***
	(0.030)	(0.022)	(0.004)	(0.005)
R^2	0.997	0.980	0.519	0.545
Obs.	66195	66203	66149	66149
	Hire Rate	Separation Rate	Worker Realloc. Rate	Job Realloc. Rate
RGGI · Begin· Utilities Sector	-0.004	0.007**	0.002	0.013***
	(0.006)	(0.003)	(0.007)	(0.004)
RGGI · Cap Lower · Utilities Sector	0.002	0.015***	0.016	0.024***
	(0.011)	(0.005)	(0.012)	(0.007)
R^2	0.847	0.792	0.916	0.805
Obs.	66134	66149	66134	66149

Notes: Dependent variable shown in column headers; All models include the following: year, quarter, and state-industry fixed effects, state-specific recessions, state-industry trends; Standard errors clustered by state-industry; *,**,*** denote statistical significance at the 10%, 5%, and 1% level, respectively.

that extracted billions of dollars that were previously uncollected. In theory, this should be equal to the social cost of carbon dioxide emissions and lead to a net improvement in social welfare because the externality-causing activity has been reduced and environmental conditions are improved. But, in practice, this is difficult to do and a policy like the RGGI could have negative effects that are more conspicuous than environmental improvement and seen immediately in the form of job losses and unemployment. What we find is that the policy did change economic outcomes for some, but that the policy did not cause the widespread harm that some may have feared. Instead, those that were displaced as a result of the policy were able to be integrated into other sectors.

7 Conclusion

In this paper we analyze the labor market effects of the Regional Greenhouse Gas Initiative, which was the first carbon emissions cap and trade policy in the United States. This is the first empirical assessment of carbon dioxide emissions pricing in the United States. The RGGI consisted of an original coalition of 10 states that includes Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. In 2012 New Jersey left the coalition, however the state rejoined the RGGI in January 2020, and both Pennsylvania and Virginia have made concrete steps toward joining the RGGI. The first auction for emissions allowances occurred at the end of 2008 (effective beginning in 2009) and the overall emissions cap was revised and subsequently lowered in 2014 with future cap reductions now more stringent than originally implemented.

The regional adoption of the RGGI and subsequent emissions cap reduction provide a unique opportunity for researchers to understand how such a cap and trade policy on a larger scale might affect workers and labor market outcomes. We adopt an empirical strategy that exploits both regional variation in the emissions policy as well as variation in the emissions cap over time. Although we adopt several empirical strategies, our specifications take advantage of a rich panel data structure that specifically distinguishes the adoption of the policy from the cap reductions.

The RGGI affects electricity producers who pollute directly since they must purchases permits to cover their CO_2 emissions. However, the RGGI can potentially affect the labor market more broadly across all industries and firms should electricity prices (an input to production) rise significantly as a result of the policy. Therefore, we also analyze the effect of the RGGI on commercial and industrial electricity prices directly, and adopt an instrumental variables approach so that we can account for electricity prices in models that estimate the demand for labor and the reallocation of workers and jobs in the labor market.

Our results suggest that the RGGI and cap reduction have had no statistical effect on employment, earnings or job reallocation in aggregate or across non-utilities industries, but there is evidence of job destruction and increased worker separation rates within the utilities sector. Evidence from the triple difference-in-differences model suggests that while there is increased job destruction and higher job reallocation in the utilities sector (but no change in employment) these destroyed jobs were likely reallocated from firms hurt by the RGGI to firms who were able to absorb these workers. Within non-Utilities industries that are classified as either industrial or commercial we uncover evidence of increased churn: higher job creation, separation, and worker reallocation rates relative to the non-RGGI area. The RGGI also does not seem to have had a significant effect on aggregate industrial or commercial electricity prices. Additionally, our results suggest the RGGI and the cap reduction have had some positive effects on worker flows and job flows in industrial and commercial sectors when we hold constant electricity price changes. To be clear, however, while the parameter estimates are statistically significant, the magnitude of the effects are relatively quite small everywhere.

Our research is a step toward understanding the labor market effects of the RGGI, and perhaps more broad ranging policies like it, but this is not a straightforward policy to evaluate and is accompanied with numerous confounding factors. For example, the carbon cap allowance was adjusted lower in 2014 because an over-supply of natural gas occurred following the advent of new oil and gas production techniques. This shock to natural gas supply brought wholesale prices down from the June 2008 high of \$12.69 per million BTU to under \$3.00 per million BTU in September of 2009, from which natural gas prices have never really recovered. This drop in natural gas prices led to a substitution away from coal which releases more CO_2 per unit of heat than natural gas. Indeed, much of the original emissions reductions goals were rendered moot by unexpected market forces and the cap tightening was necessary for the policy to be binding. Related to this abundance is the fact that allowance prices have stayed below \$8.00 – a price much lower than estimates of the social cost of carbon dioxide emissions. In addition, the 10 RGGI states do not operate within a closed electricity market nor are these states even sole producers of their own electricity. The RGGI states are part of a larger geographical group that services the Eastern Interconnection of the electricity grid (comprised of nearly all of the eastern half of the U.S.). This means electricity supplies flow in and out of RGGI states from electricity generation sites that are not subject to RGGI regulations. These complications make local regulatory impacts of the electricity market (such as the RGGI) difficult to analyze, since the localities are part a much larger system.

Setting aside the challenges of analyses like this one for a moment, our results suggest the disruptions of the RGGI appear to be minor. Indeed, the accidental implementation process of the RGGI by issuing more credits than needed may point to a politically feasible and realistic way to institute future policies with the same goals. A 'bottom up' approach of sorts that reaches eventual goals, at least in this case, that yielded emissions reductions while inflicting minimal harm in the labor market. Much like an airplane gradually descends to the ground, so too could permit allowances reach their reduction goals over time. On the surface, the positive spillover effects in non-utilities may seem like a failed placebo test, but the RGGI has extracted more than $3.7 Billion overall in just over 10 years, or about $370 Million per state. Broadly, these RGGI permit revenues have been used to fund activities like energy efficiency audits and improvements, renewable energy development, and low-carbon city services. From a revenue standpoint, much of that money has gone outside the Utilities Sector. So it could be that the positive aggregate and industrial and commercial results we see here are the consequence of those investments in RGGI funds combined with a reshaping of market incentives due to the policy. Taken at face value, our results suggest that the RGGI tax revenue is not crowding out private investment nor is it significantly raising electricity prices relative to electricity prices in non-RGGI states. Given the challenges of evaluating this policy, more research on the impacts of the RGGI is needed to confirm or reject our findings.

8 Appendix

Table A1: Table 2 with "Clean" Controls

Dep. Variable	All Industries	Electric Power	Industrial	Commercial
ln Employment				
RGGI · Begin	0.046**	0.011***	0.026	0.032***
	(0.018)	(0.003)	(0.034)	(0.010)
RGGI · Cap Lower	0.066***	0.014***	0.125***	0.052***
	(0.023)	(0.004)	(0.042)	(0.016)
ln Earnings				
RGGI · Begin	0.046**	0.045***	-0.005	0.008
	(0.018)	(0.007)	(0.011)	(0.005)
RGGI · Cap Lower	0.066***	0.051***	0.026	0.015
	(0.023)	(0.011)	(0.020)	(0.009)
Job Creation Rate				
RGGI · Begin	0.046**	0.004	0.012***	0.005***
	(0.018)	(0.004)	(0.004)	(0.001)
RGGI · Cap Lower	0.066***	0.010	0.017***	0.006***
	(0.023)	(0.010)	(0.006)	(0.002)
Job Destruction Rate				
RGGI · Begin	0.046**	0.020	-0.018***	-0.005***
	(0.018)	(0.044)	(0.005)	(0.001)
RGGI · Cap Lower	0.066***	0.050	-0.035***	-0.008***
	(0.023)	(0.060)	(0.009)	(0.002)
State FE	Y	Y	Y	Y
Industry FE	N	N	Y	Y
Year FE	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y
State Recessions	Y	Y	Y	Y
State Trends	Y	Y	N	N
State-Industry Trends	N	N	Y	Y

Notes: Unit of observation is state-quarter in the first two columns, and state-industry-quarter in the latter two columns; Robust standard errors clustered by state (first two columns) state-industry (latter two columns); *,**,*** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Table A2: Table 3 with "Clean" Controls

Dep. Variable	All Industries	Electric Power	Industrial	Commercial
Hire Rate				
RGGI · Begin	0.002	0.018	0.040***	0.023***
	(0.009)	(0.024)	(0.006)	(0.003)
RGGI · Cap Lower	0.008	0.034	0.049***	0.019***
	(0.020)	(0.041)	(0.009)	(0.004)
Separation Rate				
RGGI · Begin	0.005**	0.007	-0.004	0.005**
	(0.002)	(0.005)	(0.005)	(0.002)
RGGI · Cap Lower	0.009	0.008	-0.015*	0.002
	(0.005)	(0.007)	(0.009)	(0.002)
Worker Realloc. Rate				
RGGI · Begin	-0.001	0.000	0.038***	0.027***
	(0.002)	(0.005)	(0.007)	(0.004)
RGGI · Cap Lower	0.000	0.005	0.038***	0.021***
	(0.005)	(0.005)	(0.012)	(0.005)
Job Realloc. Rate				
RGGI · Begin	0.032***	0.020	-0.006	0.001
	(0.005)	(0.016)	(0.005)	(0.001)
RGGI · Cap Lower	0.035***	0.033	-0.018*	-0.002
	(0.008)	(0.029)	(0.009)	(0.002)
State FE	Y	Y	Y	Y
Industry FE	N	N	Y	Y
Year FE	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y
State Recessions	Y	Y	Y	Y
State Trends	Y	Y	Y	Y
State-Industry Trends	N	N	Y	Y

Notes: Unit of observation is state-quarter in the first two columns, and state-industry-quarter in the latter two columns; Robust standard errors clustered by state (first two columns) state-industry (latter two columns); *,**,*** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Figure A1: Event-study Earnings

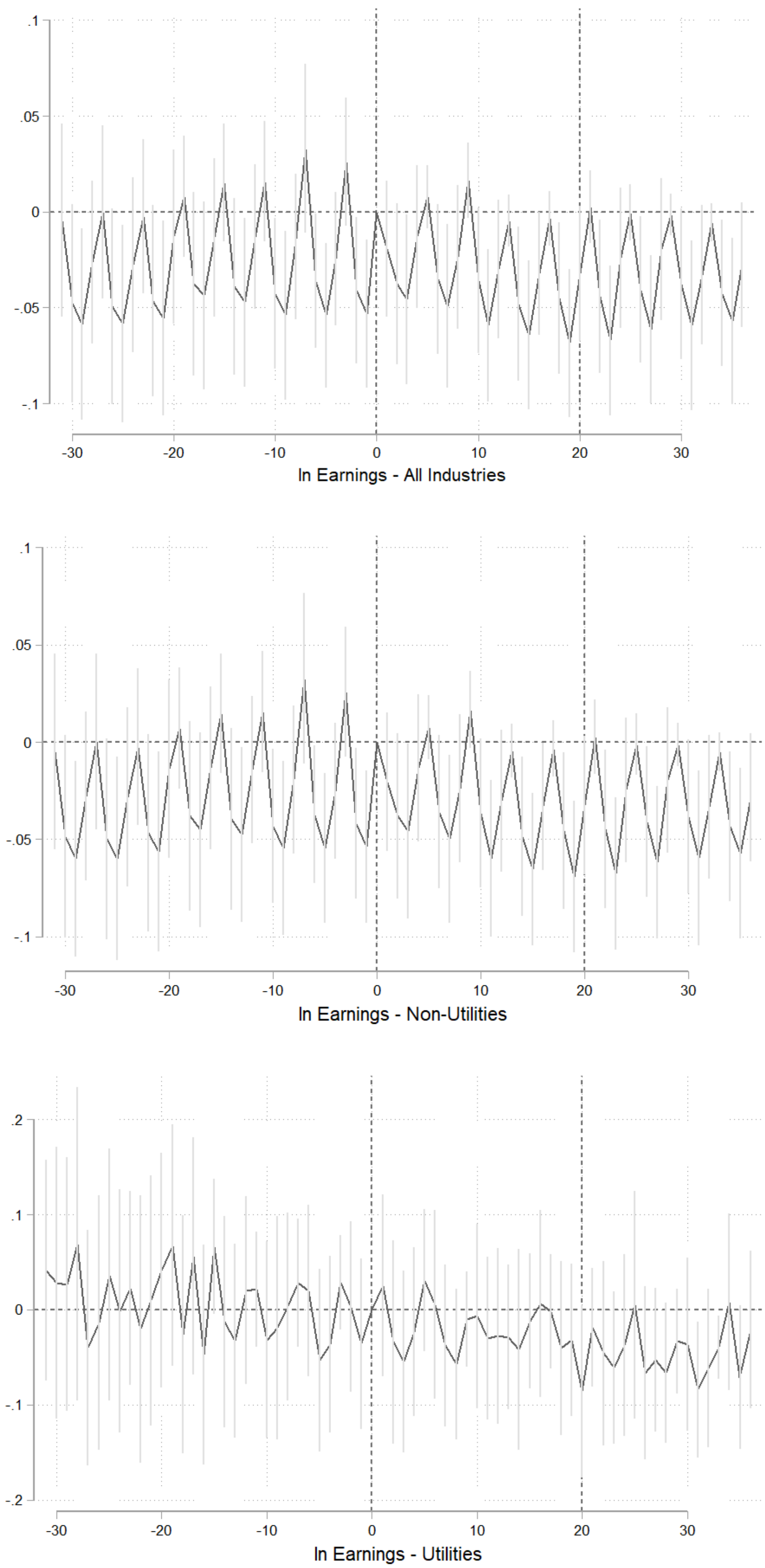


Figure A2: Event-study Job Creation Rate

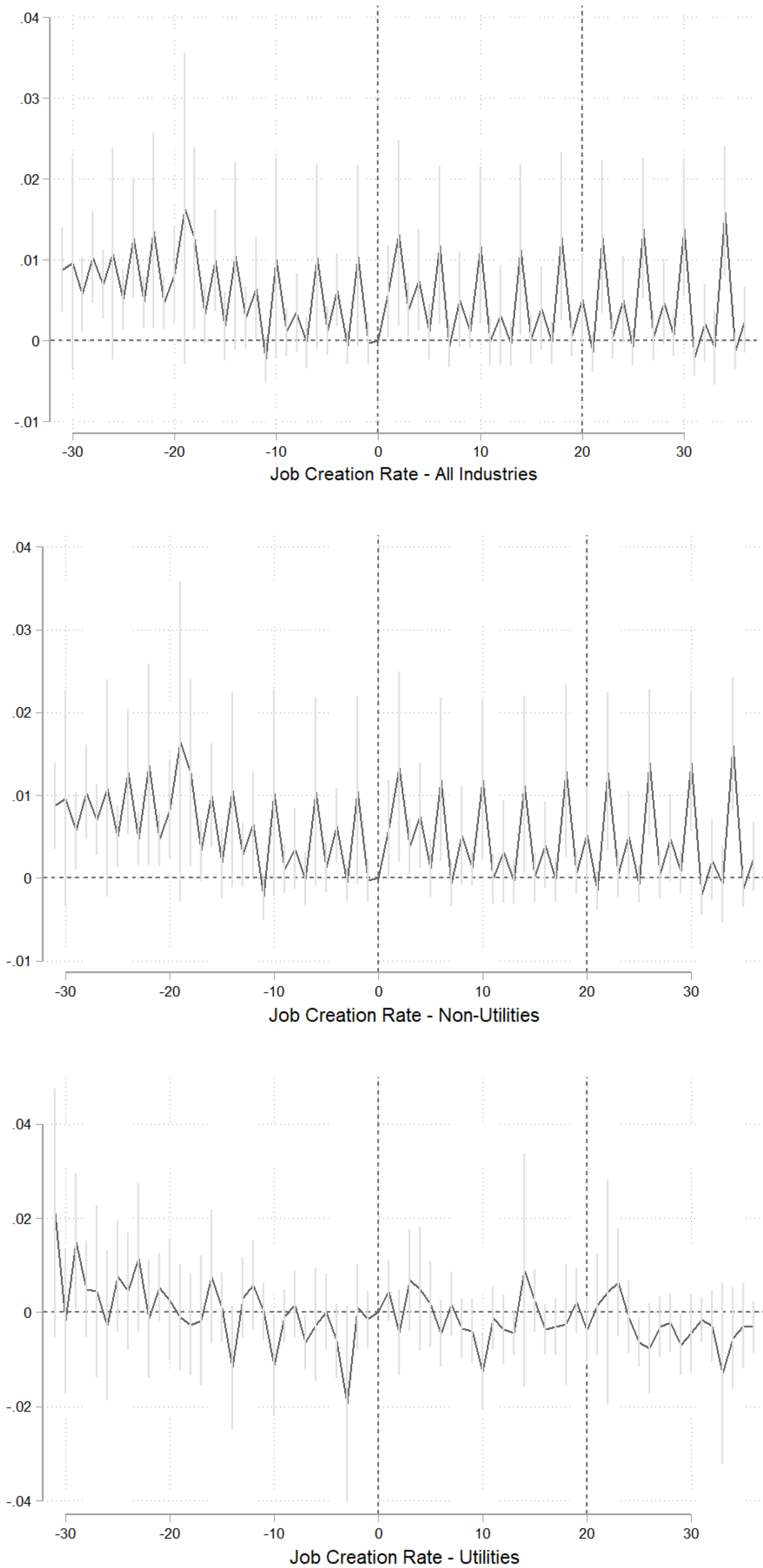


Figure A3: Event-study Job Destruction Rate

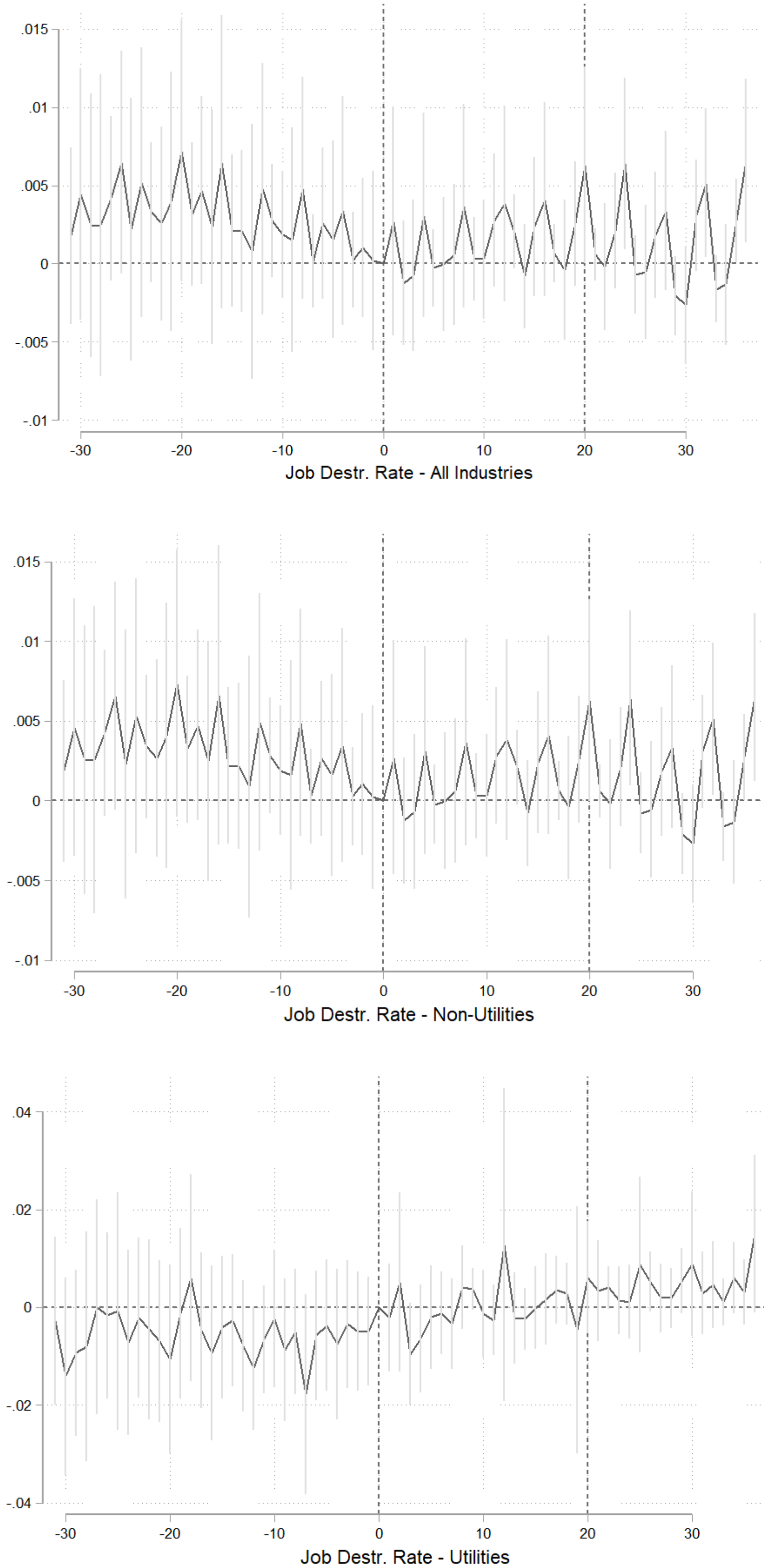


Figure A4: Event-study Hire Rate

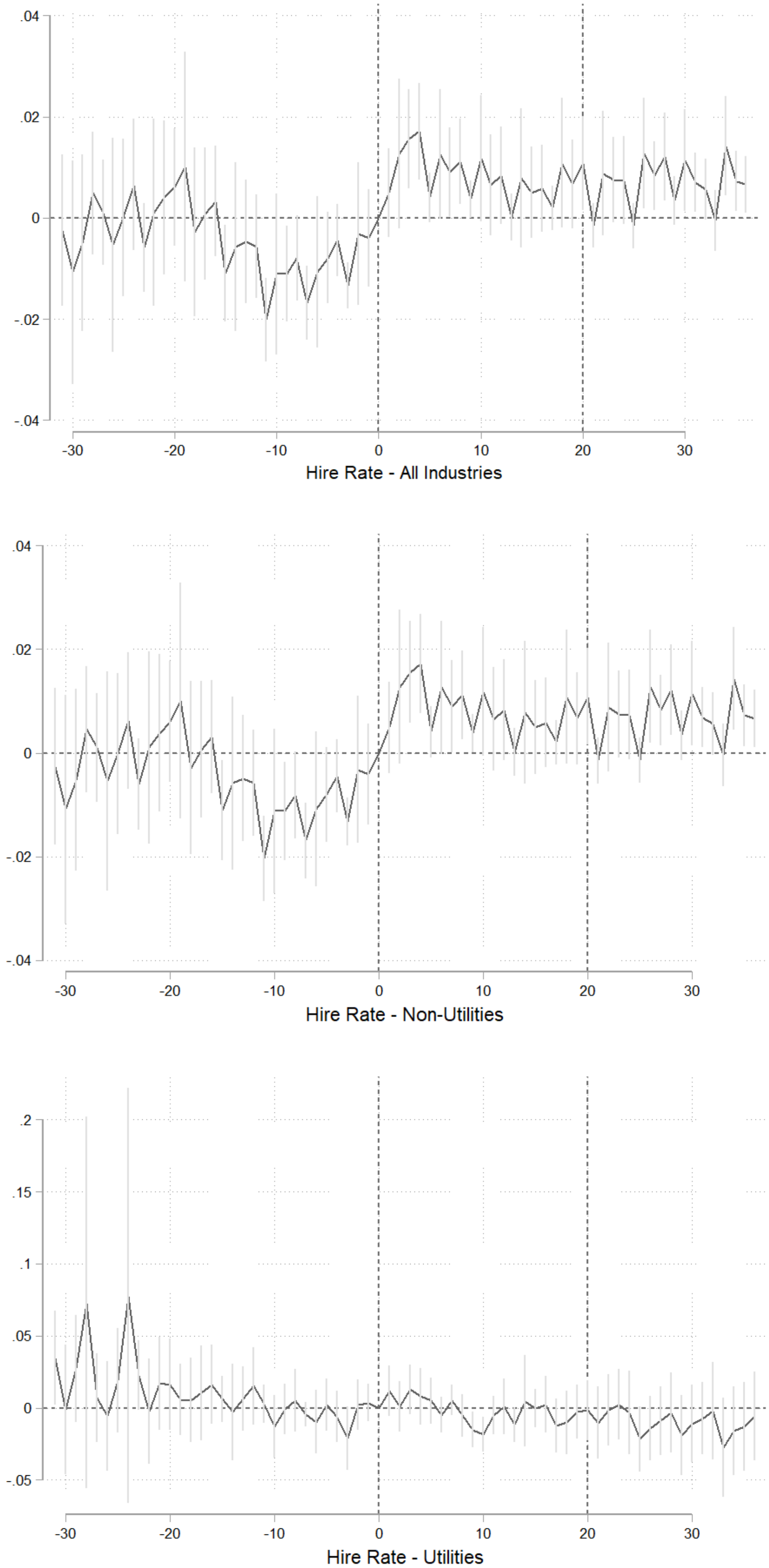


Figure A5: Event-study Separation Rate

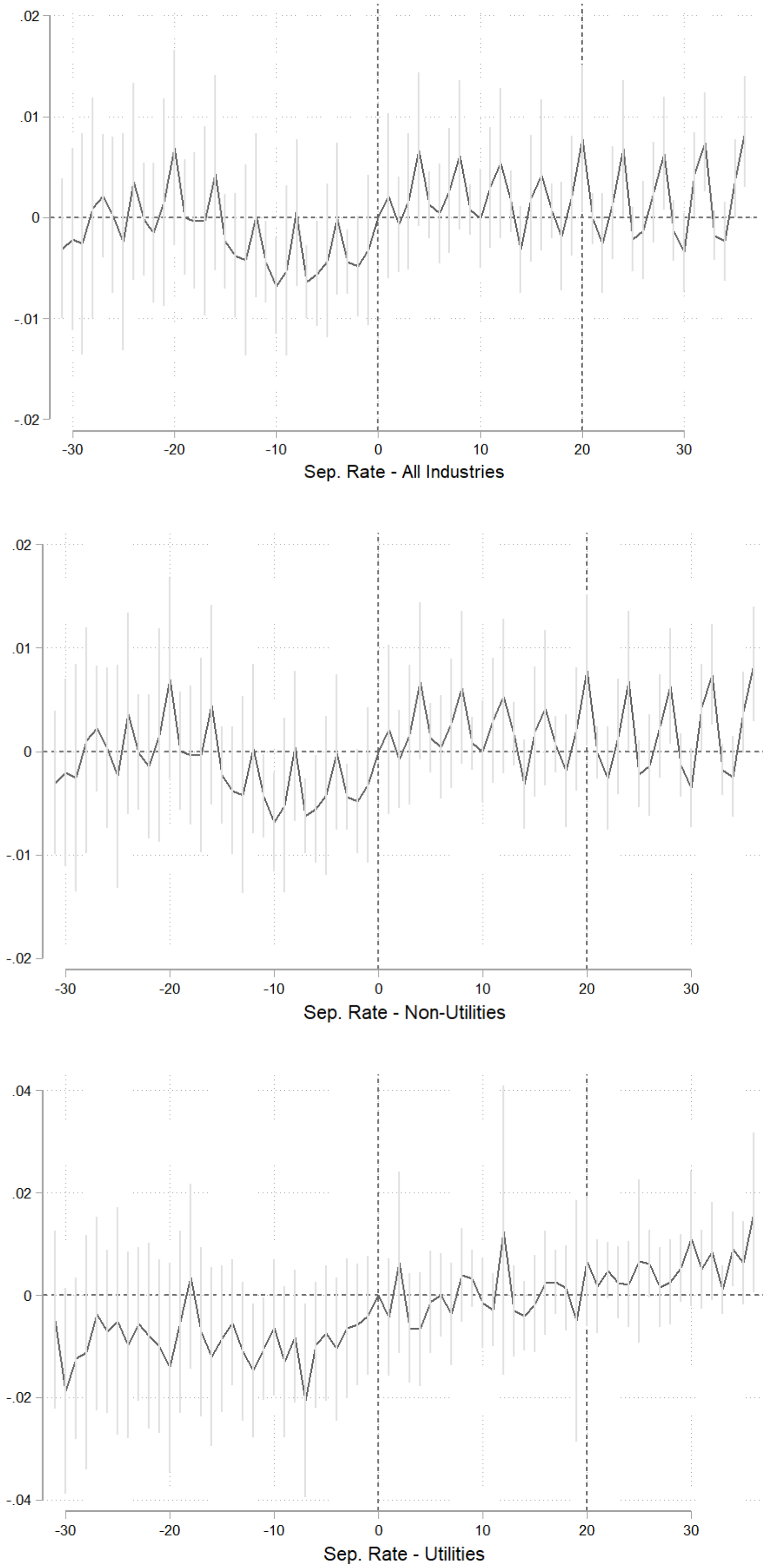


Figure A2: Event-study Worker Reallocation Rate

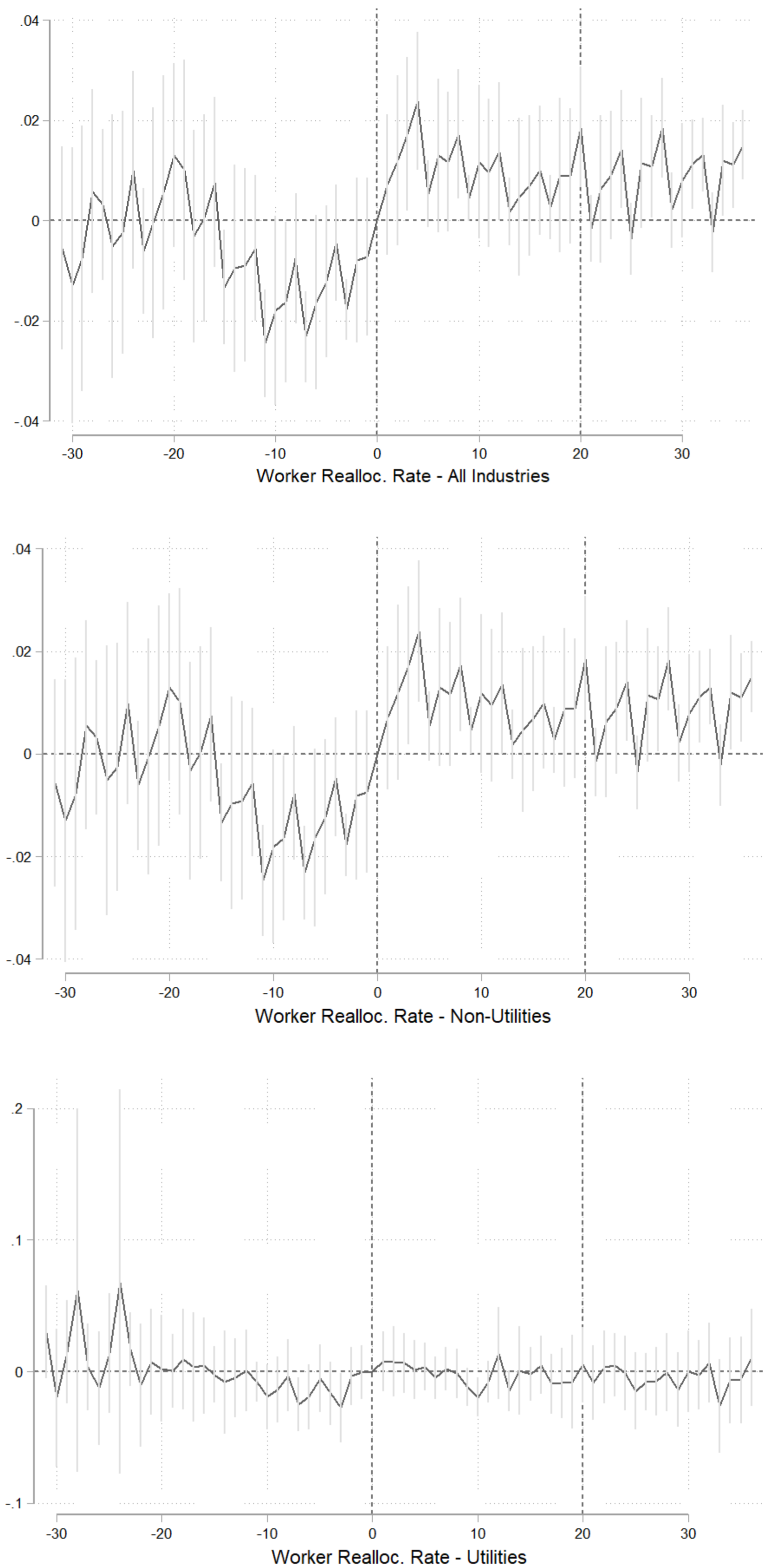
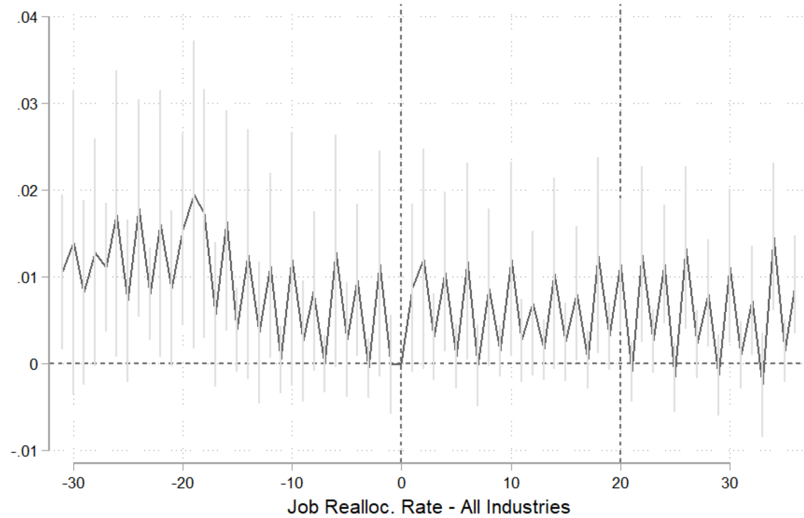
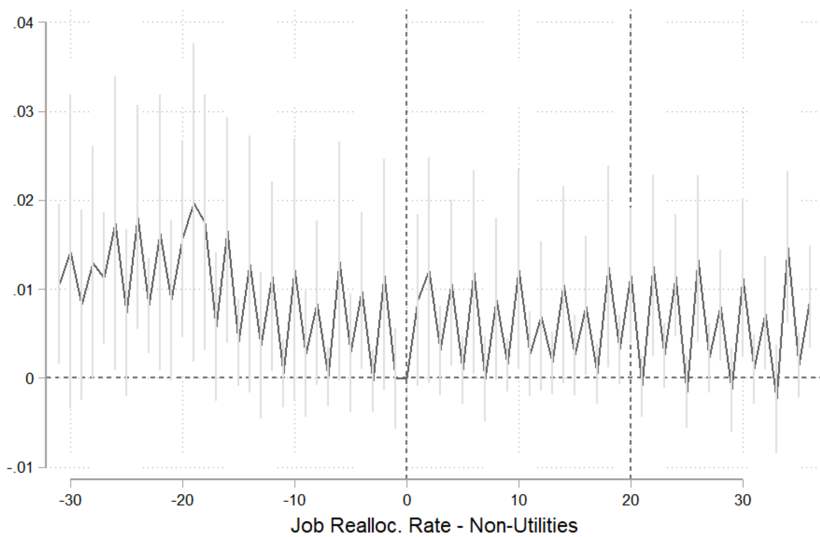
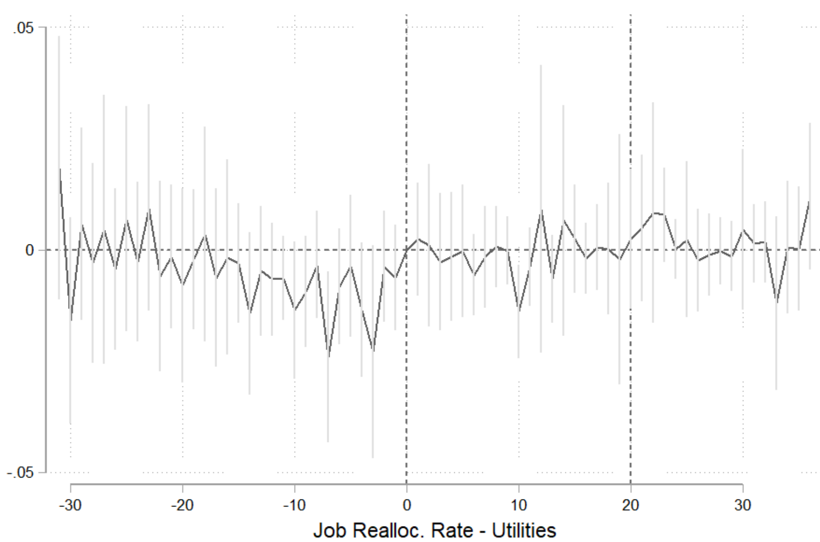


Figure A2: Event-study Job Reallocation Rate







Conflict of Interest Statement

Neither author has any conflict of interest to disclose.

References

Casey, B. J., Gray, W. B., Linn, J. and Morgenstern, R. (2020). How Does State-Level Carbon Pricing in the United States Affect Industrial Competitiveness?, *Working Paper 26629*, National Bureau of Economic Research.
URL: *http://www.nber.org/papers/w26629*

Chan, N. W. and Morrow, J. W. (2019). Unintended consequences of cap-and-trade? Evidence from the Regional Greenhouse Gas Initiative, *Energy Economics* **80**: 411–422.
URL: *http://www.sciencedirect.com/science/article/pii/S0140988319300222*

Curtis, E. M. (2017). Who Loses under Cap-and-Trade Programs? The Labor Market Effects of the NOx Budget Trading Program, *The Review of Economics and Statistics* **100**(1): 151–166.
URL: *https://doi.org/10.1162/REST*$_{a0}$0680

Fell, H. and Maniloff, P. (2018). Leakage in regional environmental policy: The case of the regional greenhouse gas initiative, *Journal of Environmental Economics and Management* **87**: 1–23.
URL: *http://www.sciencedirect.com/science/article/pii/S0095069616302984*

Foote, E. (1856). Circumstances affecting the Heat of the Sun's Rays, *The American Journal of Science and Arts* .

Kahn, M. E. and Mansur, E. T. (2013). Do local energy prices and regulation affect the

geographic concentration of employment?, *Journal of Public Economics* **101**: 105–114.
URL: *http://www.sciencedirect.com/science/article/pii/S0047272713000509*

Kim, M.-K. and Kim, T. (2016). Estimating impact of regional greenhouse gas initiative on coal to gas switching using synthetic control methods, *Energy Economics* **59**: 328–335.
URL: *http://www.sciencedirect.com/science/article/pii/S0140988316302316*

Lee, D. S., McCrary, J., Moreira, M. J. and Porter, J. (2020). Valid t-ratio Inference for IV, *arXiv:2010.05058 [econ, q-fin]* . arXiv: 2010.05058.
URL: *http://arxiv.org/abs/2010.05058*

Lee, K. and Melstrom, R. T. (2018). Evidence of increased electricity influx following the regional greenhouse gas initiative, *Energy Economics* **76**: 127–135.
URL: *http://www.sciencedirect.com/science/article/pii/S0140988318303992*

Martin, R., de Preux, L. B. and Wagner, U. J. (2014). The impact of a carbon tax on manufacturing: Evidence from microdata, *Journal of Public Economics* **117**: 1–14.
URL: *http://www.sciencedirect.com/science/article/pii/S0047272714001078*

Metcalf, G. E. and Stock, J. H. (2020a). The Macroeconomic Impact of Europes Carbon Taxes, *Working Paper 27488*, National Bureau of Economic Research.
URL: *http://www.nber.org/papers/w27488*

Metcalf, G. E. and Stock, J. H. (2020b). Measuring the Macroeconomic Impact of Carbon Taxes, *AEA Papers and Proceedings* **110**: 101–106.
URL: *https://www.aeaweb.org/articles?id=10.1257/pandp.20201081*

RGGI (2016). RGGI_proceeds_report_2014.pdf, *Technical report*, The Regional Greenhouse Gas Initiative.
URL: *https://www.rggi.org/sites/default/files/Uploads/Proceeds/*$RGGI_Proceeds_Report_2$014.pdf

Roach and Gittings (2020). Power Sector Emissions under Tightening Carbon Dioxide Quotas.

Walker, W. R. (2011). Environmental Regulation and Labor Reallocation: Evidence from the Clean Air Act, *American Economic Review* **101**(3): 442–447.
URL: *https://www.aeaweb.org/articles?id=10.1257/aer.101.3.442*

Walker, W. R. (2013). The Transitional Costs of Sectoral Reallocation: Evidence From the Clean Air Act and the Workforce*, *The Quarterly Journal of Economics* **128**(4): 1787–1835.
URL: *https://academic.oup.com/qje/article/128/4/1787/1849848*

Yamazaki, A. (2017). Jobs and climate policy: Evidence from British Columbia's revenue-neutral carbon tax, *Journal of Environmental Economics and Management* **83**: 197–216.
URL: *http://www.sciencedirect.com/science/article/pii/S0095069617301870*

Yip, C. M. (2018). On the labor market consequences of environmental taxes, *Journal of Environmental Economics and Management* **89**: 136–152.
URL: *http://www.sciencedirect.com/science/article/pii/S009506961730551X*