

Effects of the 1990 Coastal Zone Act Reauthorization Amendments
on Water Quality

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Abstract

The 1990 Coastal Zone Reauthorization Amendments (CZARA), a portion of the Clean Water Act, federally mandated coastal states to adopt management measures to regulate non-point source (NPS) pollution. Coastal states adopted management plans between 1997 and 2002, and regulated areas bordering coasts but not other areas of the state. Despite financial outlays, no work examines whether the legislation had any effect. The paper uses within-state variation in trends in counties over time to estimate the effects of regulation on water quality. This differences-in-differences-in-trends model non-parametrically controls for trends in water quality in regulated counties prior to regulation, factoring out trend changes occurring in non-regulated counties at the time of regulation. The results show substantial declines attributable to CZARA in both surface- and ground-water pollution. The largest effects occur in phosphorus, which in ten years shows a decline of 0.42 of a standard deviation in groundwater and 0.93 of a standard deviation in surface water. Simazine, the herbicide found in Roundup, shows a ten-year decline of 0.19 of a standard deviation.

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I. Intro

In 2005, nearly half of the U.S. population lived in coastal counties even though these counties constituted only one quarter of the nation's land.¹ These areas also saw the highest population growth and most development since 1985. To protect coastal water quality, preserve property values, and support fisheries, the federal and state governments have passed several pieces of legislation since 1972. Despite over thirty years of laws, in 2005 the EPA declared the state of the nation's coastal waters to be between "fair" and "poor" (EPA, 2005). This dismal state has been attributed to difficult-to-regulate non-point source (NPS) pollution, usually from agricultural and urban run-off. Given the EPA's reported disparity between CWA legislation and results, examination of effects of legislation is necessary to understand efficacy in improving water quality. This paper examines the impacts on water quality of the most recent NPS federal legislation governing coastal areas, the 1990 Coastal Zone Act Reauthorization Amendments (CZARA).

CZARA, also known as the Coastal Nonpoint Source Program, united sections of the Clean Water Act and the Coastal Zone Management Program in federally mandated legislation. Following guidelines set forth by the EPA and the National Oceanic and Atmospheric Administration (NOAA), states wrote and implemented management plans focused mainly on urban development and agriculture. States could choose from a variety of implementation mechanisms, from economic incentives to rules. Regulation focused on coastal areas (usually entire counties), while leaving non-coastal areas

¹ Author's calculations from U.S. Census data.

unregulated. Failure to implement the management plan resulted in large reductions in federal funding.

In order to examine whether the CZARA had any effects on water quality, I assemble a variety of annual government data at the county level for the period 1985 to 2001. I compile data on the dates states originally adopted the federal CZARA guidelines to ascertain when coastal counties move from being unregulated to regulated. To control for trends and events within regulated states, I construct a control group of counties contiguous to the coastal counties. The structure of this regulation data allows for cross-sectional, longitudinal, and within state variation in regulation. I assemble a dataset of over 100,000 ground- and surface-water quality observations from the U.S. Geological Survey (USGS), to test for differences in agricultural and urban pollutants including nutrients, oils, metals, and pesticides. The empirical strategy using the combined data relies on differences-in-differences in trends models which control for differentials in trends before and after state legislation, factoring out trend changes in control counties.

While legislation has frequently been passed to protect and clean the nation's water, very little consistent assessment has been conducted to actually discover if these laws have made any impact. Little reliable monitoring has been performed since the beginning of the CWA, unlike the case of Clean Air Act, which established fixed monitors at many locations across the nation. The EPA's best attempt to determine whether national water quality has been improving comes in periodic reports entitled *The State of the Nation's Waters*. These survey varying portions of water bodies to determine whether they are

able to support their designated uses (for example, recreation). Standards across states for what constitutes “use” are not consistent, and different portions of water bodies are tested in each report. The lack of consistency has made testing of water legislation’s effects difficult. Adler, Landman, and Cameron (1996) spend an entire book describing possible sources of data (excluding the one used in this article), the exact problems with them, and why we can’t be certain that the Clean Water Act had any impact on water quality, despite the fact that rivers no longer catch fire.

In addition to being one of the first to econometrically exam the Clean Water Act, this paper speaks to several lines of research. Several papers have explored whether environmental regulations impact economic development. Greenstone (2002) and Henderson (1996) both exploit the Clean Air Act’s division of counties into attainment and non-attainment to measure the impact of regulation on industrial activity. Greenstone finds that regulated counties suffered significant economic losses, while Henderson shows polluting industries moving to less-polluted areas.

While the economics literature has not examined water legislation’s effect on pollution, it has examined the Clean Air Act’s effects on air pollution. These studies provide useful guidelines for similar types of research. Chay and Greenstone (2005) use the institution of the 1970 Clean Air Act to examine effects on air quality. Using the Clean Air Act’s division of counties into attainment and non-attainment to identify effects, these authors reveal a substantial impact of legislation on air quality. Henderson (1996) also examines

the Clean Air Act's assignment of counties to attainment and non-attainment status, revealing pollution concentrations just below one of the regulatory standards.

The article reveals that CZARA regulation caused changes in trends in several measures of ground- and surface-water quality. Groundwater nitrogen, phosphorus, mercury, total coliform, and mercury all show significant declines after legislation, netting out trends in non-regulated inland counties. Surface water quality shows improvement in nitrogen, phosphorus, total coliform, and simazine (the herbicide in Roundup). The largest effects occur in phosphorus, which declines an additional 0.42 of a standard deviation over a ten-year period in groundwater, and 0.93 of a standard deviation in surface water.

II. Regulation Variation in CZARA

The ideal method of finding the effect of legislation on environmental quality would mimic a controlled laboratory experiment in which legislation is randomly assigned to different locations. Examining the differences in outcomes for regulated locations versus unregulated ones would provide the "true" effect of the legislation. Without a random assignment, a useful option is to find a situation in which similar areas face different levels of regulation. This section describes how the structure and adoption of CZARA allow for such a situation.

A. Background of CZARA and Enforcement

In its most recent assessment of the nation's waters, the EPA found that non-point source (NPS) pollution originating from agricultural and urban run-off was the number one

source of water quality impairment (EPA, 2000). NPS pollution, also known as polluted run-off, occurs when precipitation carries pollutants through and over the ground to underground aquifers and surface waters. An example of NPS pollution includes crop-applied pesticides that reach nearby streams via snow melt. NPS pollution can be contrasted with point-source (PS) pollution, which arises from a specific point of origin like a discharge pipe. While PS pollution can be regulated via restrictions on the “point,” NPS pollution originates from diffuse sources and is therefore less easily regulated. Based on this difficulty, water quality legislation is mainly focused on PS pollution.

The EPA has voiced concern over NPS pollution since the 1972 Clean Water Act. At this time, the Coastal Zone Management Act authorized the Coastal Zone Management Program, a federal-state partnership enacted to protect and maintain the nation’s coastal resources. The conglomeration of state-based CWA policies and CZMA programs between 1972 and 1990 lacked consistent enforcement and regulatory bite (Adler, Landman, Cameron, 1993) and focused almost entirely on point-source pollution. Frustrated with the lack of attention to NPS pollution, Congress passed the 1990 Coastal Zone Act Reauthorization Amendments (CZARA). These introduced new mandatory legislation to control NPS pollution in lands bordering coasts.

CZARA affected 35 states and territories, which were required to submit management plans. Of the states, most regulated just coastal counties and not all counties within the state. The act also allowed for fining and reduction in grants from federal programs. States have varying times of adoption ranging from 1997 to 2003.

In order to clean coastal waters, CZARA set forth certain guidelines. Implementation varied by state, but all states needed to show that they met federal guidelines. Guidelines centered on six main areas: agriculture, hydromodification, forestry, wetlands, urban areas, and marinas and recreational areas. Briefly, descriptions of these six areas and the CZARA management measures for them are the following:

Agriculture: Agricultural practices include both crop and livestock production.

CZARA recommended various management techniques to discourage run-off and erosion. These included filter strips, contour farming, conservation covers, and crops planted to uptake excess nutrients.

Hydromodification: Hydromodification refers to changing the flow of water, usually for drainage improvement or protection of human life. Examples include channelization, Hydromodification can alter the flow of water, resulting in lowered supply of freshwater and changes in sedimentation. Management measures include modeling possible effects, and the employment of “best professional judgement” (EPA, 2007).

Forestry: Forestry practices (silviculture) can affect sediment deposits by destabilizing soil. The construction of roads for logging can lead to increased run-off. Fertilizer applied to tree cropping also leads to water pollution. Management measures include limiting new road construction, better management practices, and construction of retaining walls.

Wetlands: Wetlands often serve to reduce NPS pollution by collecting nutrient run-off, but can also suffer from NPS pollution problems. Therefore, the goal is to keep certain wetlands functioning as pollution sinks and to reduce the flow of pollution to others. Acquisition and zoning serve to keep certain wetlands protected from being drained. Management practices to reduce NPS pollution to wetlands include buffer strips and enforcement of water quality standards.

Urban areas: Along with agriculture, urbanization is the other main culprit in NPS pollution. Urbanization increases run-off through paving over porous surfaces, reducing vegetative areas that once absorbed nutrients, inadequate stormwater drainage leading direct deposits of sewage to surface waters, and oil products from vehicles can pollute waters.

Marinas and recreational boating: Problems with boating center not just on the pollutants from boats (oil, sewage), but also changes to habitats created by changing waterfronts. Management measures therefore include marina flushing, which means making sure the water does not become stagnant, and restrictions on new and expanding marinas.

These federal guidelines targeted specific industries. Regulation mostly affected agricultural and urban development practices. Livestock farming operations, one of the main contributors of non-point source pollution, were considered a main culprit.

Considering urban development practices, the regulations did not restrict building per se, just the types of things that could be built. Further restrictions could lead to less construction or building, and could conceivably hurt the overall economic climate of the area.

States that did not submit management plans by the deadline faced removal of funding under the Coastal Zone Management Act and the Clean Water Act. While the CZARA was adopted in 1990, states had until 1996 to submit program statements outlining their intended methods to abide by the guidelines. Failure to submit by 1996 led to a 10 percent reduction in funding under both the CZMA and the CWA, increasing to 15% in 1997, 20% in 1998, and 30% in 1999. States could submit conditional approval programs by 1996 in order to avoid funding penalties.

Despite the funding penalties, no state actually had a finalized program by 1996; the first conditional approval programs were submitted in 1997, followed by another state in 1998. Several states did not submit conditional approval programs until 2002 and 2003.

B. What pollutants were targeted by CZARA?

CZARA targeted the major non-point source pollutants, including agricultural and urban run-off. While the legislation was also concerned with sedimentation and erosion, this section focuses on the water pollutants targeted.

Agricultural run-off arises from two types of practices: livestock and crop production. In the case of livestock production, manure is deposited on land as a method of disposing of this main byproduct of the industry. With the disaggregation of crop and livestock farming, manure is most frequently applied to cover crops rather than crops for harvest. Manure is rich in nitrogen and phosphorus; when precipitation carries the manure from the surface of the land either to ground or surface water, it can lead to nutrient loading. Manure can also lead to higher coliform levels in ground and surface water.

Crop production is another agricultural activity leading to water pollution. Fertilizers, herbicides, and pesticides applied to crops can leach into groundwater or can be carried over land to surface waters. Man-made fertilizer can lead to nutrient loading of the same variety seen from livestock production.

Urban practices indicated in the CZARA lead to pollutants in the form of oils, salts, and metals, as well as pesticides and herbicides used in lawn care. Urban non-point source pollutants include the metals mercury, arising from industrial wastewater and atmospheric deposition, and chromium, arising from metal alloys, paint pigments, cement, paper, and rubber.

C. Variation in Regulation due to CZARA

The structure and adoption of the CZARA regulations allow for identification of effects of regulation through three sources of variation. This section specifies these three

sources and highlights why they provide an identification strategy that controls for many conceivably contaminating variables.

Starting in 1997 with the first set of counties that adopted the policy, CZARA created cross-sectional variation across counties. Some counties were regulated, while other coastal counties remained unregulated. Looking at one point in time means that both treatment and control counties will be affected by whatever shocks in water quality and economic activity that are pertinent to that time period. Any time-specific shocks will affect treatment and control observations similarly and therefore the identification strategy controls for this possibility.

A second source of variation useful for identification of legislation effects is variation over time. Counties on the coasts move from being unregulated to regulated. Variation over time within counties can be used to identify changes specific to counties and enables separating effects due to regulation from those specific to the individual county. This also enables controlling for county-specific fixed effects that might be correlated with outcomes. This is especially useful in the case of environmental features which are unlikely to change in a 21-year period.

Finally, the legislation creates variation within states within years. Within states, only coastal counties are regulated. The other counties in most regulated states were not subject to CZARA.² Examining differences between counties within states in individual

² Some states only regulated portions of their coastal counties. This means that results will underestimate the true effects of the regulation.

years controls for state-level effects in the form of regulation stringency and enforcement as well as other state-level regulatory activity.

III. Data and Summary Statistics

Data from seven different government sources are merged by county and year to form a panel data set of 626 treatment (coastal) counties and 249 inland (control) counties between 1985 and 2005.

A. Data sources and structure

Data on implementation dates of Coastal Nonpoint Pollution Control Program of the 1990 CZARA comes from the National Oceanic and Atmospheric Administration's (NOAA) listing of program approvals.³ Counties were characterized as coastal by individual inspection of state maps, and then compared to the NOAA listing of coastal counties for verification. The U.S. Census Bureau's Area Resource File was then used to identify counties contiguous to regulated ones. Contiguous counties that were outside of regulated states (as in the case, for example, of Delaware) were excluded for consistency with other states. Not all states regulated the entirety of coastal counties; some only regulated a portion of the county nearest to the coast. Future analyses will calculate the portion of the county that is regulated using GIS software; until then, results on the effect of regulation will be underestimates.

³ The conditional and full approval conditions of all states and territories can be found at http://coastalmanagement.noaa.gov/nonpoint/pro_approve.html.

Surface- and ground-water quality data arises from the U.S. Geological Survey's (USGS) online National Water Inventory System (NWIS). This contains data on water quality from several million sites in the nation. The USGS does not maintain statistics on coastal water quality. The NWIS contains data for every water quality sample taken in the country by various USGS-related organizations. Not all locations have been sampled repeatedly. Discrete water quality samples were downloaded for all states, yielding a dataset of over 100,000 observations. In order to provide more consistency between water quality samples and to reduce the likelihood of outliers, only water quality observations listed as "routine sample" and having a sample type of "regular" (not following a major storm, for example) are included. Many types of water quality tests can be performed for a specific pollutant. When there is more than one test, I choose the water quality measure with the most observations. The USGS collects data on hundreds of water quality measures, but many of these have limited frequency. Due to the limited number of observations on certain pollutants, I restrict my analysis to looking a select number of outcomes. For groundwater, these include nitrogen, phosphorus, total coliform, mercury, and chromium, and for surface water these include nitrogen, phosphorus, total coliform, mercury, chromium, and the herbicides simazine (the chemical in Roundup) and metolachlor.

Covariates for individual water quality observations include month of sample and, for groundwater, well-depth. Data on county-level time-varying controls arise from several sources. I construct a population density variable by dividing county-level inter-censual population projections from the U.S. Census Bureau by the county's total land area in

square miles. Per capita income (in 2005 dollars) by county comes from the BEA Regional Economic Accounts.

Precipitation and temperature variables come from the U.S. Historical Climate Network. These provide annual precipitation and temperatures for 1,221 locations; from these I constructed county-level variables, assigning temperature and precipitation values according to state climate division when necessary.

B. Longitudinal Incidence of Regulation

States adopted conditional CZARA legislation in 1997, 1998, 2002, and 2003. Table 1 shows the number of coastal counties that are regulated and unregulated in each period, as well as the number of inland counties (which are never regulated). There are a total of 654 coastal (“treatment”) and 243 inland (“control”) counties. Table 1 shows that with each of the four years in which regulation was adopted, a significant number of observations move from unregulated to regulated. This *intra*-county variation allows for the inclusion of county fixed effects. The *inter*-county variation in regulation status allows for state-year fixed effects in subsequent analyses.

C. Is regulation orthogonal to observable determinants of water quality and industry?

Ideally, one would like regulation to not be related to other determinants of water quality so that we can attribute changes in outcomes to regulation. While it is possible to compare (and control for) observables, there is still the worry that unobservable variables will be correlated with regulation and therefore a correlation between regulation and

outcome may be the result of the unobservable, rather than the regulation itself. In order to mitigate this possibility, we can look first at observable characteristics. If observables are the same for treatment and control counties, then we are more likely to have orthogonality among the unobservables.

Tables 2a and 2b provide evidence as to whether the inland counties serve as legitimate controls for the coastal counties. The table shows determinants to water quality as well as water quality levels in the period before any regulation took place (1985-1996). The table is divided to show variables for states that adopted legislation in each of the four years (1997, 1998, 2002, or 2003). For example, comparison of the values in columns 1(a) and 1(b) shows that counties in states that adopted CZARA in 1997 were similar in many ways to counties that did not fall under regulatory purview. This holds true for states that adopted in the other years. The only very obvious differences are in population and population density. Coastal counties had much higher population densities than inland counties.

An alternative counterfactual is comparing counties that were regulated in certain years and comparing them to counties regulated in later years (comparing column 1(a) with 2(a), for example). This type of comparison would be appropriate in econometric models without inland counties in the sample, and without state-year fixed effects. While these comparisons also show similarities, there are a few notable differences. States that adopted earlier were more likely to have lower poverty rates than states that adopted

later. This is consistent with an environmental Kuznets curve hypothesis in which wealthier areas are more likely to adopt environmental regulation.

Table 2b shows similar comparisons as Table 2a, but for water quality measures. Average annual changes in water quality are different but not markedly so when considering scale in terms of the means. Coastal counties generally have higher rates of increase in water pollution.

Given the similarities between coastal and inland counties in observables, there is a higher likelihood that regulation is uncorrelated with unobservables. However, given the dissimilarities, it is necessary to use econometric methods to control for possible unobservables that may bias results.

III. Empirical strategy

The identification strategy exploits the proximity between regulated and non-regulated counties. Figure 1 provides a schematic showing four counties: A, B, C, and D.

Counties A and B are on the coast and are therefore subject to regulation, while counties C and D lie inland and thus are not subject to regulation. Counties A and B are therefore treatment counties, while C and D are controls. Counties A and C are in one state, while B and D lie in another. The identification strategy exploits differences within states between inland and coastal counties, and therefore uses the differences between A and C and between B and D to identify effects.

Begin by considering an equation of the following form:

$$(1) \quad Y_{icst} = I REG_{cst} + X'_{icst} \mathbf{b} + Z'_{cst} \mathbf{b} + \mathbf{g}_c + \mathbf{g}_t + \mathbf{g}_{st} + e_{icst}$$

This is a standard differences-in-differences approach where i denotes the individual water quality observation, c denotes county, s references state, and t indexes year. The term Y_{icst} is the dependent variable denoting the output variable for observation i in county c in state s in time t . REG_{cst} is a dummy variable equal to 1 when a county is under CZARA regulation and 0 when not. X'_{icst} is a set of observation-, time-, state-, and county-varying covariates. Z'_{cst} is a set of time-, state-, and county-varying covariates. \mathbf{g}_c , \mathbf{g}_t , and \mathbf{g}_{st} denote county, time and state-year fixed effects. County fixed effects non-parametrically absorb the characteristics of individual counties that do not change in the 21-year period of observation. The year fixed effects absorb shocks that occur in all counties specific to a certain time period. State-year dummies control for events that happen to all counties in a specific state and year, such as state-level policies.

In this estimation, the regulation effect I is purged of many sources of bias. The fixed effects control for all county-specific, unobserved, permanent determinants of development, all unobserved year-specific factors common to regulated and unregulated counties within a state, and all unobserved transitory factors common to all counties in a specific time period.

While the standard DD model controls for a number of possible factors potentially biasing results, it does not control for possible differences in trends between treatment

and control groups. If pollution in coastal counties is increasing faster (slower) than inland counties, then a standard differences-in-differences model may yield a positive (negative) effect of the legislation even though there is no impact. This could be true even if means in treatment and control counties are similar. A different model is therefore necessary to control for a potential lack of orthogonality in growth rates between growth and treatment group :

$$(2) \quad Y_{icst} = \mathbf{b}_1 \text{Trend}_{cs} + \mathbf{b}_2 (\text{Trend} * \text{Post} - \text{regulation})_{cs} \\ + \mathbf{b}_3 (\text{Trend} * \text{Coastal})_{cs} + \mathbf{b}_4 (\text{Trend} * \text{Coastal} * \text{Post} - \text{regulation})_{cs} \\ + X'_{icst} \mathbf{b} + Z'_{cst} \mathbf{b} + \mathbf{g}_c + \mathbf{g}_{st} + e_{icst}$$

In this specification, “Trend” is a time trend, “Post-regulation” is a dummy variable equal to one when the state has adopted regulation, and “Coastal” is a dummy variable equal to one when the county is on the coast and eventually gets regulated. The other variables denote the same factors as in equation (1). In equation (2), the estimated \mathbf{b}_1 denotes the estimated increase in the outcome variable in the inland counties in the years prior to legislation being enacted in the state. $\mathbf{b}_1 + \mathbf{b}_3$ provides the estimated trend in the outcome variable for coastal counties prior to legislation. \mathbf{b}_3 denotes the estimated difference in trend between inland and coastal counties prior to legislation. If coastal counties are growing at different rate than inland counties prior to legislation, then \mathbf{b}_3 will be significant. $\mathbf{b}_1 + \mathbf{b}_2$ is the estimated trend for inland counties in years after regulation is enacted in the state. If \mathbf{b}_2 is significant, this suggests that the regulation had an effect on the control group. $\mathbf{b}_1 + \mathbf{b}_2 + \mathbf{b}_3 + \mathbf{b}_4$ provides the trend in coastal counties after CZARA adoption. \mathbf{b}_4 denotes the estimated difference in trend between inland and

coastal counties after legislation. If b_4 is significant, this indicates that the trend in the coastal counties post-legislation (the treated group after treatment) is different from the inland counties post-legislation (the control group after the treatment group has been treated). The model controls for an event occurring in the same year as legislation that affects both inland and coastal counties in the same manner. Figure 2 provides a schematic of this empirical strategy.

IV. Results

Tables 3 and 4 show regression results for water quality measures as well as overall means and standard deviations of measures.⁴ Table 3 shows groundwater, and Tables 4a and 4b show surface water measures. The highlighted rows denote the estimates of b_4 from Equation (2) above. Results of two models are shown for each outcome as a robustness check. The model in the (a) columns includes all fixed effects as well as individual water-quality observation controls. The model in the (b) columns includes time-varying county-level covariates.

The results show that CZARA regulation had a statistically significant impact on water quality trends. CZARA caused groundwater nitrogen levels to decrease at a rate of 0.003mg/L per year faster than control counties. In ten years, this yields an additional decline of 0.03mg/L, or about 0.05 of a standard deviation. For a ten-year period, phosphorus declines an additional 0.42 of a standard deviation, total coliform declines an

⁴ Due to the large number of observations with zero-values for pollutants, logging the water quality measures would have a significant impact on the sample size.

additional 0.03 of a standard deviation, mercury has a 0.08 standard deviation change, and chromium has a 0.11 standard deviation change.

Examining effects of CZARA on surface water quality shows larger results in terms of standard deviations. For the statistically significant results, surface water nitrogen declines 0.42 of a standard deviation in 10 years faster than control counties, phosphorus declines 0.93 of a standard deviation, total coliform declines 0.68 of a standard deviation, and simazine declines 0.19 of a standard deviation. Effects on surface-level mercury, chromium, and metolachlor do not show statistically significant effects.

IV. Discussion and Conclusion

The results show substantial declines attributable to CZARA in both surface- and ground-water pollution using an identification method that non-parametrically absorbs many sources of bias. The largest effects occur in phosphorus, which in ten years shows a decline of 0.42 of a standard deviation in groundwater and 0.93 of a standard deviation in surface water. Surface-level total coliform and nitrogen also show substantial changes with legislation. Despite the smaller effects in surface-level simazine and groundwater mercury, these chemicals have potentially large health risks; thus, even small declines may be worth large outlays.

Full comprehension of the size of water quality effects requires comparison of these results with the effects of other legislation or placing a dollar value on preferences for water quality. Little research has examined effects of water quality legislation, limiting

this as a source of comparison. Contingent valuation or hedonic studies valuing preferences for water quality are necessary to estimate the benefits of the legislation.

Additionally, studies estimating the effects of water quality changes on

In order to compare the benefits of CZARA with the costs, it is necessary to calculate not just the resources devoted to putting the legislation into place, but also estimating the effects that regulation has on economic development. If the regulations caused businesses and employment to relocate, this impact in terms of lost tax dollars may offset any benefits. Future work therefore needs to explore not just the mechanisms leading to these reductions in water pollution, but also the costs associated with economic impacts.

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Figure 1: Representation of Identification Strategy

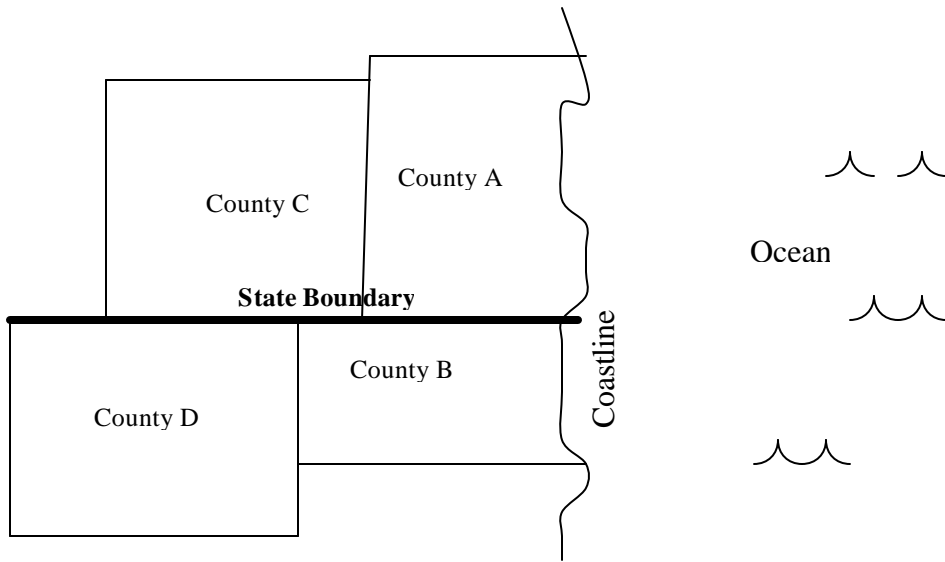


Figure 2: Representation of Empirical Model

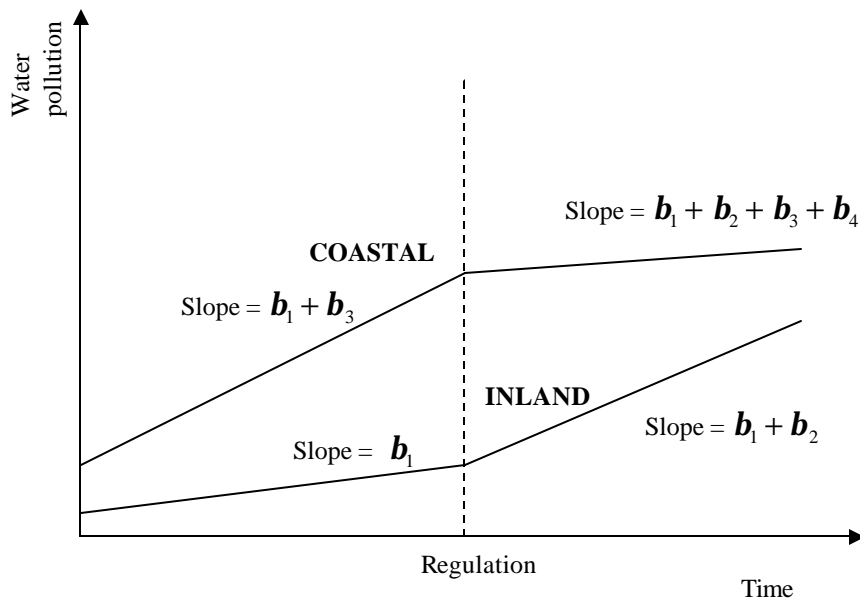


Table 1: Number of Counties Regulated Versus Unregulated, by Period

	Period				
	Pre-1997	1997	1998-2001	2002	2003-2005
Eventually regulated:					
Regulated	0	283	559	609	654
Unregulated	654	371	95	45	0
Never regulated:					
Controls	243	243	243	243	243

Table 2a: Comparison of Water Quality Determinants in Coastal and Non-Coastal Counties

Year of regulation:	Mean Levels and Rates in 1985-1996							
	1997		1998		2002		2003	
	Coastal	Non-coastal	Coastal	Non-coastal	Coastal	Non-coastal	Coastal	Non-coastal
Number of counties	283	88	276	92	50	37	45	26
Population	225,040	103,134	191,863	78,554	97,579	51,854	133,413	32,996
Average annual population growth rate, 85-96	1.25%	0.73%	1.11%	1.29%	0.97%	0.51%	0.54%	2.76%
Population density	1075.5	205.0	480.4	76.7	233.1	109.1	114.2	37.6
Per capita income (2005\$)	\$26,274	\$23,162	\$25,030	\$22,752	\$22,787	\$21,294	\$20,964	\$19,049
Average annual growth in per capita income, 85-96	4.80%	4.78%	4.86%	4.85%	4.80%	4.92%	3.51%	3.92%
Precipitation (inches)	44.7	42.1	48.6	40.3	44.2	44.9	40.6	37.7
Temperature (F)	54.4	49.9	58.9	58.5	58.9	59.7	66.6	63.2
Elevation (feet above sea level)	405	728	147	710	447	530	231	518
Land area (square miles)	653	725	935	1,490	454	445	1,130	1,098

Table 2b: Comparison of Water Quality in Coastal and Non-Coastal Counties

Mean Levels and Changes in 1985-1996								
Year of regulation:	1997		1998		2002		2003	
	Coastal	Non-coastal	Coastal	Non-coastal	Coastal	Non-coastal	Coastal	Non-coastal
Groundwater								
Nitrogen	0.020	0.018	0.035	0.098	0.011	0.012	0.011	0.010
Average annual change 85-96	-0.003	-0.010	0.001	-0.069	-0.002	-0.002	-0.004	0.002
Phosphorus	0.122	0.021	0.357	0.152	0.015	0.067	0.025	0.073
Average annual change 85-96	0.003	0.000	0.199	0.236	--	-0.002	0.000	-0.085
Total Coliform	26.69	10.59	17.47	11.81	9.68	--	--	--
Average annual change 85-96	1.095	-1.560	--	6.508	--	--	--	--
Mercury	0.357	0.136	0.112	0.452	--	--	--	--
Average annual change 85-96	2.341	0.044	0.028	-0.423	--	--	--	--
Chromium	9.353	4.384	6.269	10.800	15.862	3.704	6.636	3.833
Average annual change 85-96	-1.051	0.001	-2.716	0.225	3.680	--	--	--
Surface Water								
Nitrogen	0.033	0.016	0.050	0.036	0.037	0.022	0.033	0.018
Average annual change 85-96	-0.001	0.001	0.006	0.001	0.001	-0.014	-0.003	0.002
Phosphorus	0.311	0.030	0.094	0.070	0.045	0.029	0.276	0.276
Average annual change 85-96	0.008	-0.025	-0.004	-0.011	0.045	-0.005	0.019	0.009
Coliform	6215.0	8695.7	1955.3	930.1	--	--	--	--
Average annual change 85-96	6168.0	9891.6	-91.4	-1208.6	--	--	--	--
Mercury	0.228	0.115	0.122	0.192	0.167	0.157	0.433	0.118
Average annual change 85-96	-0.069	-0.0004	-0.008	-0.019	-0.075	-0.031	--	0.011
Chromium	2.818	1.839	1.771	2.344	2.432	4.091	4.254	4.394
Average annual change 85-96	-0.070	0.028	-0.232	-0.357	-0.181	-1.269	-1.175	-0.699
Simazine (Herbicide)	0.116	0.060	0.063	0.104	0.070	0.028	0.031	0.011
Average annual change 85-96	0.189	-0.002	0.005	-0.013	--	-0.032	0.101	--
Metolachlor (Herbicide)	0.265	0.257	0.173	0.072	1.247	0.589	0.024	0.002
Average annual change 85-96	-0.079	-0.084	0.034	-0.014	--	0.258	0.002	--

Table 3: Differences-in-differences in trends regressions of groundwater quality on trends pre- and postregulation

	Dependent variable									
	Nitrogen		Phosphorus		Total coliform		Mercury		Chromium	
Mean:	0.027		0.143		126.1		1.29		16.34	
Standard deviation:	(0.591)		(0.861)		(2964.9)		(28.83)		(122.18)	
Model:	1(a)	1(b)	2(a)	2(b)	3(a)	3(b)	4(a)	4(b)	5(a)	5(b)
Trend	-0.037 (0.026)	-0.006 (0.005)	-0.028 (77.333)	-0.060 (0.029)*	-2.130 (0.953)*	-2.757 (1.895)	-0.022 (0.011)*	0.102 (0.064)	-0.725 (0.822)	467.389 (3.887)**
Trend*Regulation enacted in state	0.018 (0.013)	0.005 (0.003)	0.021 (.)	0.053 (0.026)*	2.436 (0.393)**	3.218 (0.570)**	-0.035 (0.013)**	0.000 (0.000)	0.094 (0.658)	-444.719 (1.531)**
Trend*Coastal	0.038 (0.026)	0.007 (0.003)*	0.040 (0.021)	0.042 (0.024)	1.876 (1.990)	2.514 (1.843)	0.011 (0.008)	-0.121 (0.082)	0.837 (0.646)	0.128 (0.754)
Trend*Coastal*Regulation enacted in state	-0.019 (0.014)	-0.003 (0.001)*	-0.034 (0.016)*	-0.036 (0.017)*	-6.050 (1.058)**	-7.611 (1.100)**	0.029 (0.012)*	-0.023 (0.009)*	-1.149 (0.686)	-1.285 (0.628)*
Well depth	-0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-0.005 (0.005)	-0.006 (0.005)	-0.000 (0.000)	0.000 (0.000)	-0.006 (0.003)*	-0.010 (0.004)**
Mean temperature		-0.008 (0.007)		-0.021 (0.041)		-11.147 (2.872)**		-0.116 (0.070)		0.261 (2.223)
Precipitation (inches)		-0.000 (0.000)		0.000 (0.000)		0.001 (0.001)		-0.000 (0.000)**		0.001 (0.001)
Per capita income (\$05)		-0.002 (0.002)		0.004 (0.005)		-0.320 (0.593)		0.011 (0.012)		0.229 (0.214)
Population density		-0.000 (0.001)		0.006 (0.004)		10.432 (17.073)		0.005 (0.009)		3.305 (3.847)
Month of observation controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
County fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
State*year fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	18,311	14,564	19,041	15,486	1,835	1,789	2,050	1,832	7,918	6,478

Robust standard errors clustered at the level of the county in parentheses. * significant at 5% level; ** significant at 1% level

Table 4a: Differences-in-differences in trends regressions of surface water quality on trends pre- and postregulation

	Dependent variable									
	Nitrogen		Phosphorus		Total coliform		Mercury		Chromium	
Mean:	0.043		0.261		14,248.4		0.521		15.58	
Standard deviation:	(0.354)		(0.961)		(126,731.8)		(18.98)		(122.05)	
Model:	1(a)	1(b)	2(a)	2(b)	3(a)	3(b)	4(a)	4(b)	5(a)	5(b)
Trend	-0.000 (0.002)	-0.004 (0.004)	-0.005 (0.005)	-0.146 (0.061)*	-245.706 (224.050)	-15,664.911 (8,059.620)	-0.049 (0.009)**	-0.027 (0.016)	-3.133 (0.338)**	-0.867 (0.342)*
Trend*Regulation enacted in state	0.007 (0.004)	0.010 (0.005)	0.021 (0.015)	0.095 (0.039)*	23.680 (77.175)	-3,028.387 (3,277.869)	0.023 (0.008)**	-0.008 (0.009)	0.712 (0.133)**	0.055 (0.177)
Trend*Coastal	0.001 (0.002)	0.004 (0.004)	0.000 (0.007)	0.072 (0.052)	358.340 (423.377)	18,171.076 (9,877.021)	-0.002 (0.002)	-0.005 (0.004)	-0.302 (0.265)	-1.233 (0.560)*
Trend*Coastal*Regulation enacted in state	-0.007 (0.004)	-0.015 (0.006)*	-0.019 (0.014)	-0.089 (0.038)*	-126.775 (220.876)	-8,606.082 (4,076.925)*	0.001 (0.001)	0.002 (0.001)	0.012 (0.074)	0.126 (0.164)
Mean temperature		0.034 (0.021)		0.043 (0.037)		22,340.401 (19,190.331)		0.014 (0.029)		0.366 (0.921)
Precipitation (inches)		0.000 (0.000)		0.000 (0.000)		-4.296 (6.471)		0.000 (0.000)**		0.000 (0.000)
Per capita income (\$05)		0.001 (0.001)*		0.002 (0.003)		-594.373 (1,050.009)		0.003 (0.002)		-0.028 (0.092)
Population density		-0.033 (0.012)**		-0.091 (0.033)**		313,414.739 (180,416.162)		0.049 (0.039)		0.623 (0.559)
Month of observation controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
County fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
State*year fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	12,912	9,507	8,194	5,880	3,761	1,614	6,842	4,180	7,655	4,840

Table 4b: Differences-in-differences in trends regressions of surface water quality on trends pre- and post-regulation

	Dependent variable			
	Simazine (Herbicide)		Metolachlor (Herbicide)	
Mean:	0.098		0.146	
Standard deviation:	(1.50)		(1.34)	
Model:	6(a)	6(b)	7(a)	7(b)
Trend	-0.065 (0.021)**	-0.035 (0.025)	-0.031 (0.069)	-0.089 (0.093)
Trend*Regulation enacted in state	0.019 (0.005)**	0.010 (0.008)	0.022 (0.012)	0.067 (0.030)*
Trend*Coastal	0.051 (0.017)**	0.064 (0.023)**	-0.000 (0.020)	0.008 (0.027)
Trend*Coastal*Regulation enacted in state	-0.021 (0.007)**	-0.028 (0.010)**	0.001 (0.010)	-0.003 (0.017)
Mean temperature		0.003 (0.030)		0.011 (0.056)
Precipitation (inches)		-0.000 (0.000)		0.000 (0.000)
Per capita income (\$05)		0.011 (0.003)**		0.010 (0.006)
Population density		0.003 (0.016)		-0.039 (0.027)
Month of observation controls	Y	Y	Y	Y
County fixed effects	Y	Y	Y	Y
State*year fixed effects	Y	Y	Y	Y
Observations	11,536	8,847	11,827	9,112