Who Loses Under Power Plant Cap and Trade Programs?

Estimating the Impact of the NO_x Budget Trading Program on Manufacturing Employment

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Background

- Considerable Controversy over EPA Regulation of Energy Sector
  - WSJ Editorial: “The Latest Job Killer from the EPA”
  - Washington Post Wonk Blog: “Getting Ready for a Wave of Coal Plant Shutdowns”

- “...Counties risk losing jobs when businesses respond to the higher costs and uncertainty by closing marginal facilities and siting new facilities elsewhere, including outside the U.S.”

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Background: EPA Regulations

- Command and Control
  - National Ambient Air Quality Standards (NAAQS)
    - County-level attainment standards
    - Empirical work by Greenstone (2002), Walker (2012), Kahn and Mansur (2011)

- Cap and Trade Programs
  - Acid Rain Program (SO_2)
    - Nationwide program
    - Structural work by Burtraw et al. (1998)
  - NOx Budget Trading Program (NBP)
    - Regional Program
    - Palmer et al, (2001); Deschenes et al. (2011)

Preview of Methodology and Results

- Use DDD to exploit geographic, time and industry variation of NBP
- Large sets of fixed effects
- NBP caused a loss of between 70,000 and 130,000 manufacturing jobs

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History and Description of the NBP

- 1990 Clean Air Act Amendments (CAAA)
  - Strengthened Section 126: EPA's mandate to regulate interstate air pollution
- In 1998 EPA grants petition by northeastern states and agrees to regulate NO_x emissions from Southern, Midwestern States
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  - Northeastern States unable to meet NAAQS attainment standards
  - Smog causes numerous health concerns: Asthma, Chronic Lung Diseases

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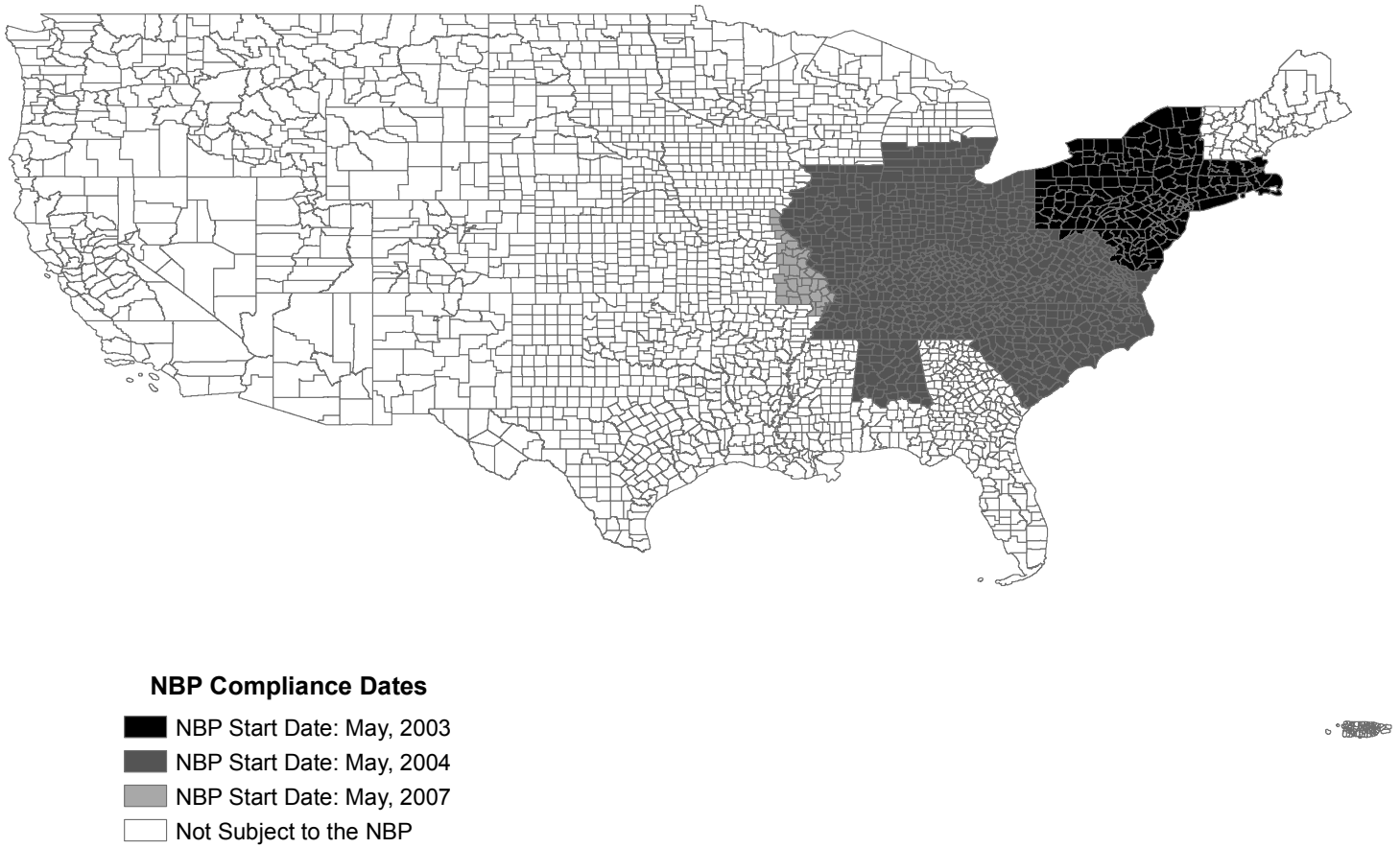
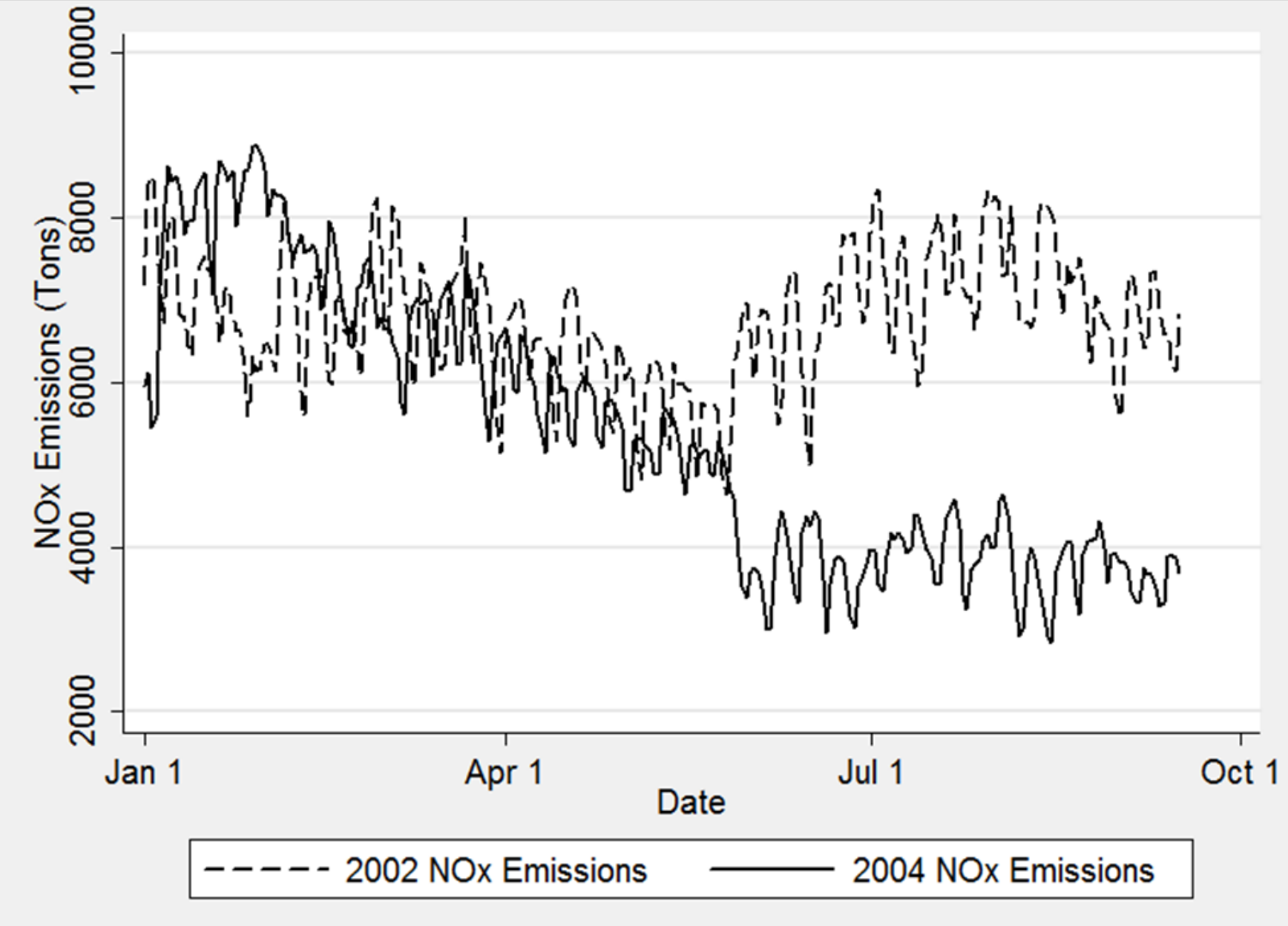
History and Description of the NBP

- Met with heavy resistance from electric utilities as well as Southern and Midwestern States
  - *Michigan et al. vs. EPA et al.* in 2000 upheld legality of NBP as did *Appalachian Power et al. vs. EPA* in 2002
  - Lawsuits and petitions continued with varying degrees of success, but in June, 2004 2,500 energy producing establishments in 19 states began compliance with the NBP
- Eight states joined in 2003, eleven more joined in 2004
- Applied to 2,100 electric generating units and 400 large industrial plants

NBP Compliance Region



NOx Emissions in 2002 and 2004



Utilities' Response to the NBP

- Utilities had difficult and costly compliance decisions to make leading up to 2004
- Options:
  1. Shift from coal to other energy sources (natural gas)
  2. Use and purchase permits
  3. Invest in NOx reducing technologies

Upshot of NBP

- Significant costs required to decrease pollution
  - Industry cost of around $2 billion annually (Palmer et al, 2001) or around $3 million annually per coal fired plant
- Estimated 1-2% increase in price of electricity
- Uncertainty for energy sector / energy consumers

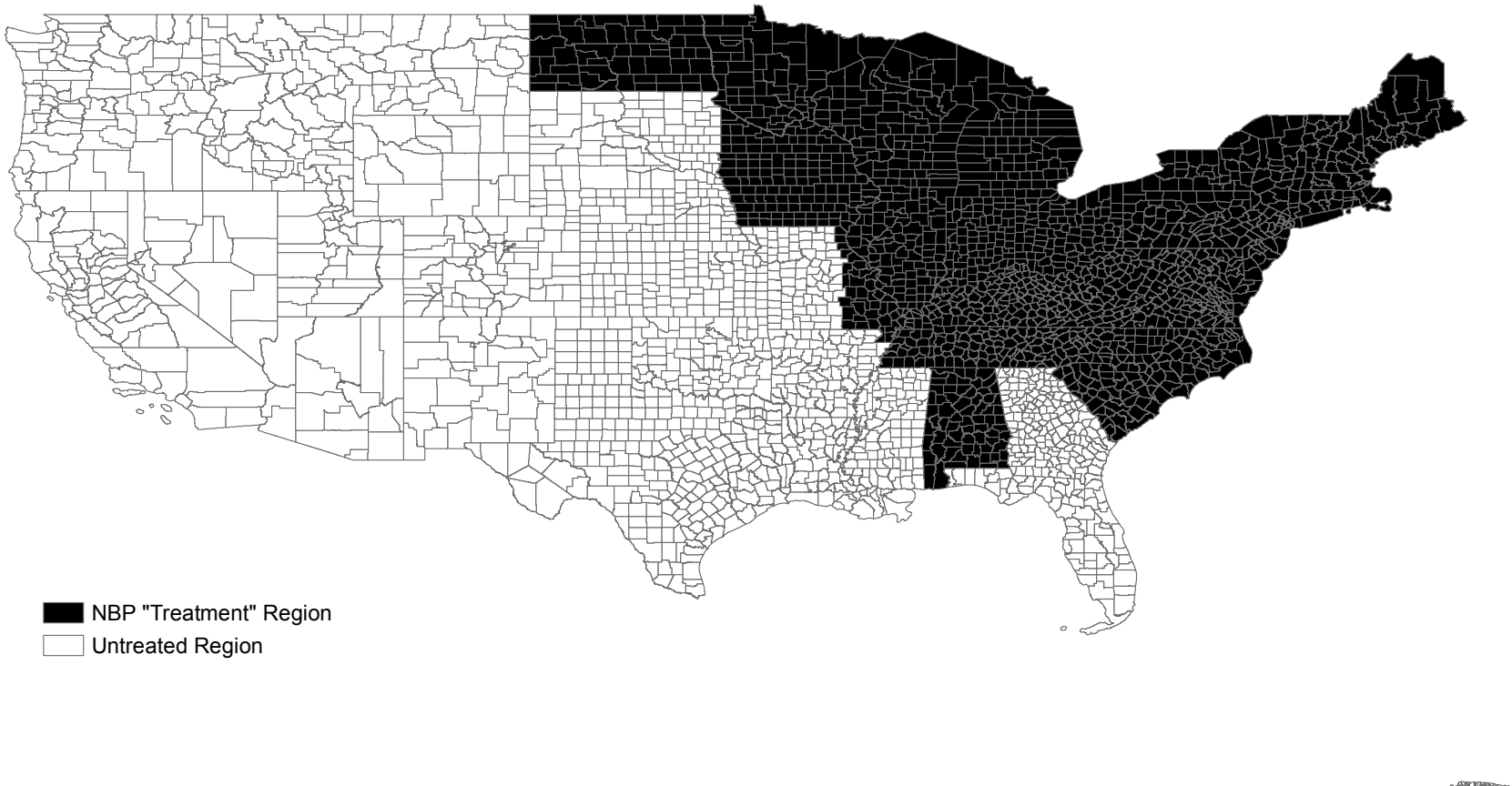
Data

- County Business Patterns: Yearly sub-national economic data by industry (1998-2009)
  - Publicly available, derived from the Business Registry
  - Unit of observation is a county-industry
- NBER Productivity Database
  - Based on Census of Manufactures
  - Industry level data on Total Value of Shipments, Energy Expenditure

Variable Definitions

- Variables
  - $lemp_{ckt}$: log of employment in county c, industry k in year t
  - $Post_{ct}$: = 1 for years 2005-2009 (= 1 for northeastern states in 2004)
  - $East_c$: = 1 for counties impacted by the NBP
  - $EnInt_k$: = $EnergyExpenditure_k$ / $GrossOutput_k$

Treated Region



Industry Energy Intensity Measure

NAICS 3-digit Code	Industry Description	Energy Intensity Level
311	Food Manufacturing	1.45%
312	Beverage and Tobacco Product Manufacturing	0.71%
313	Textile Mill	3.47%
314	Textile Product Mill	1.32%
315	Apparel Manufacturing	1.03%
316	Leather and Allied Product Manufacturing	0.97%
321	Wood Product Manufacturing	1.83%
322	Paper Manufacturing	4.32%
323	Printing and Related Support Activities	1.26%
324	Petroleum and Coal Products Manufacturing	2.88%
325	Chemical Manufacturing	3.25%
326	Plastics and Rubber Products Manufacturing	2.17%
327	Nonmetallic Mineral Product Manufacturing	4.96%
331	Primary Metal Manufacturing	5.46%
332	Fabricated Metal Product Manufacturing	1.58%
333	Machinery Manufacturing	0.78%
334	Computer and Electronic Product Manufacturing	0.62%
335	Electrical Equipment, Appliance, and Component Manufacturing	1.00%
336	Transportation Equipment Manufacturing	0.62%
337	Furniture and Related Product Manufacturing	0.97%
339	Miscellaneous Manufacturing	0.78%

Base DDD Model

Consider the Following Econometric Specification:

$$\begin{aligned} lemp_{ckt} = \beta_T(Post_{ct}xEast_cxEnInt_k) + \beta_1(Post_{ct}xEast_c) \\ +\beta_2(Post_{ct}xEnInt_k) + \beta_3(East_cxEnInt_k) \\ +\beta_4(Post_{ct}) + \beta_5(East_c) + \beta_6(EnInt_k) + \eta_{ckt} \end{aligned}$$

Where,

- $Post_{ct}$: = 1 for years 2005-2009 (= 1 for northeastern states in 2004)
- $East_c$: = 1 for counties impacted by the NBP
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$\beta_1 - \beta_6$ drop out as we include Fixed Effects

Full Fixed Effects DDD Model

With a full set of interacted fixed effects the model becomes:

$$lemp_{ckt} = \beta_T(Post_{ct}xEast_cxEnInt_k) + \beta_C(X_{ckt}) + \delta_{ck} + \gamma_{ct} + \alpha_{kt} + \varepsilon_{ckt}$$

Where,

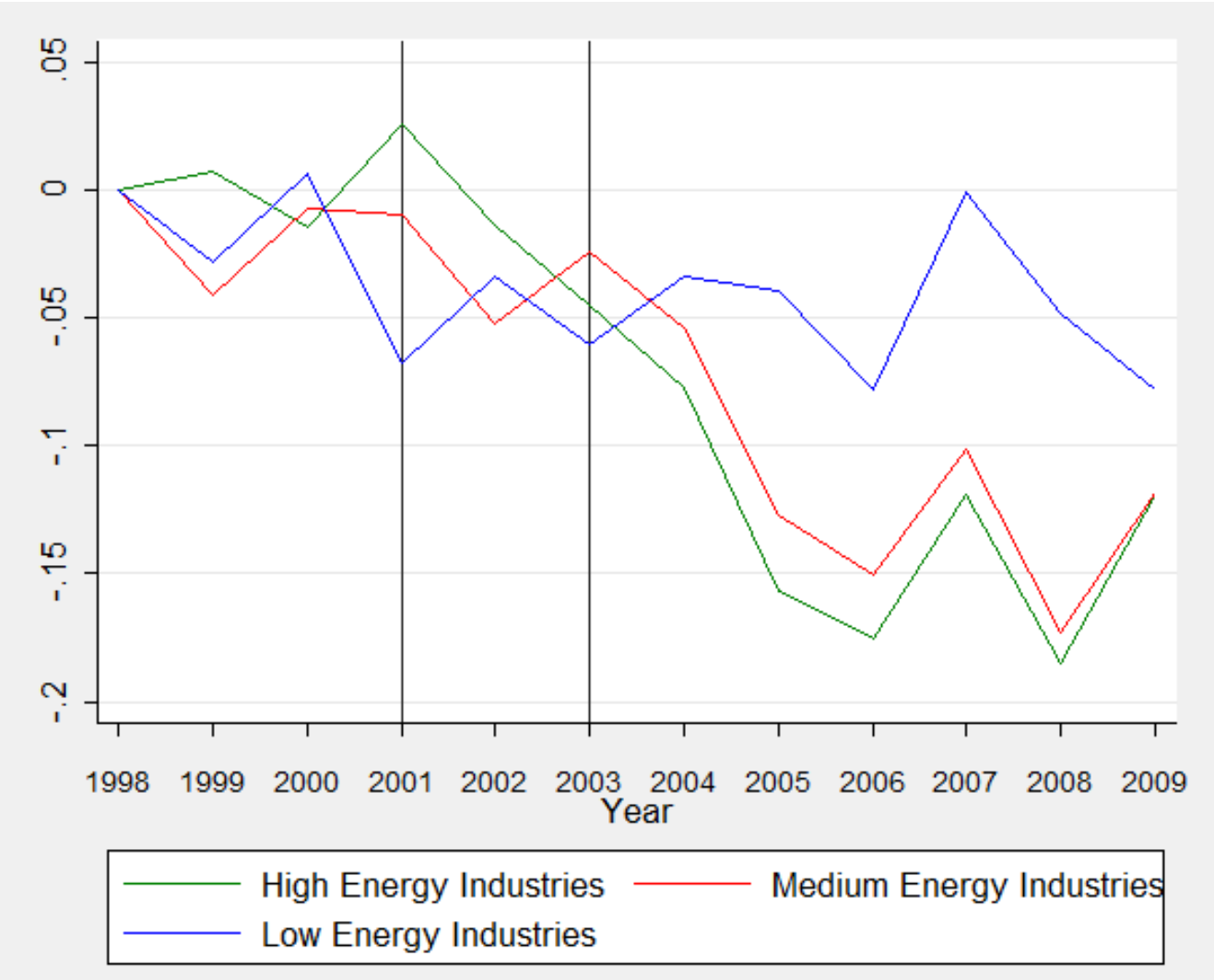
- X_{ckt}: Vector of Controls
- δ_{ck}: Vector of Cty-Ind Indicator Variables
- γ_{ct}: Vector of Cty-Year Indicator Variables
- α_{kt}: Vector of Ind-Year Indicator Variables

Diff-in-Diff Identification

- Differing Trends
- Unobserved Events
  - Change in NAAQS attainment standards
  - Change in fuel costs
- Spillovers
  - From East to West
  - From High Energy Industries to Low Energy Industries
- Interpretation
  - Job loss and job transition
  - Walker (2012); Davis and Von Wachter (2011)

East-West Difference in Employment by Industry Grouping

% Change in East - % Change in West (Using 1998 as Baseline)



Regression Results: Reported Manufacturing Data

	1	2	3	4	5	6	7	8
		(IndxYear FE)	(CtyxYear FE)	(CtyxInd FE)	(CtyxInd FE)	(CtyxInd FE)	(CtyxInd FE)	(CtyxInd FE)
VARIABLES	lemp	lemp	lemp	lemp	lemp	lemp	lemp	lemp
PostxEastxInt	-1.804***	- 1.224	-. 9678	-1.791***	-1.338**	-.9131**	-1.008*	-1.303**
	(.7882)	(3.554)	(1.116)	(.5437)	(.5215)	(.4587)	(.6175)	(.6315)
PostxEast	. -.0370**	-. 0433	.	-. 0330***	. 0355**	-. 0009	.	.
	(.0172)	(.0638)		(.0117)	(.0116)	(.0099)		
Cty FE	Yes	Yes						
Ind FE	Yes		Yes					
Year FE	Yes			Yes	Yes	Yes		
NAAQS Controls				Yes	Yes	Yes	Yes	Yes
Cty Trend					Yes	Yes		
Ind Trend					Yes			
E/W Ind Trends		Yes				Yes		Yes
IndxYear			Yes				Yes	
CtyxYear							Yes	Yes
Observations	144,968	144,968	144,968	144,968	144,968	144,968	144,968	144,968
R-squared	. 5367	. 5411	. 5758	. 9553	. 9577	. 9578	.9622	.9594

Standard Errors are Robust to heteroskedasticity and are clustered at the county-industry level. The dependent variable is the ln(employment+1)

Robustness Checks

- Dropping MISO States
- Excluding 2009
- Missing Data
- State Level

Regression Results: State Level

	1	2	3	4	5	6	7	8
		(IndxYear FE)	(StatexYear FE)	(StatexInd FE)	(StatexInd FE)	(StatexInd FE)	(StatexInd FE)	(StatexInd FE)
VARIABLES	lemp	lemp	lemp	lemp	lemp	lemp	lemp	lemp
PostxEastxInt	- 3.067***	- 3.188***	- 3.375***	- 2.592***	- 2.487***	- 2.541***	- 2.382***	- 2.101***
	(0.9807)	(1.121)	(1.163)	(1.075)	(0.8537)	(0.7295)	(0.9543)	(0.8249)
PostxEast	-.0333	-.0165	.	- 0549**	.0051	-.0065	.0378	.0031
	(0.0242)	(0.0302)		(0.0272)	(0.0163)	(0.0143)	(.1128)	(.0556)
State FE	Yes	Yes						
Ind FE	Yes		Yes					
Year FE	Yes			Yes	Yes	Yes		
State Trend					Yes	Yes		
Ind Trend					Yes			
E/W Ind Trends						Yes		Yes
IndxYear		Yes					Yes	
StatexYear			Yes				Yes	Yes
Observations	10,135	10,135	10,135	10,135	10,135	10,135	10,135	10,135
R-squared	.7996	.8058	. 8020	. 9860	. 9923	. 9916	. 9918	. 9921

Standard Errors are Robust to heteroskedasticity and are clustered at the state-industry level. The dependent variable is the ln(employment+1)

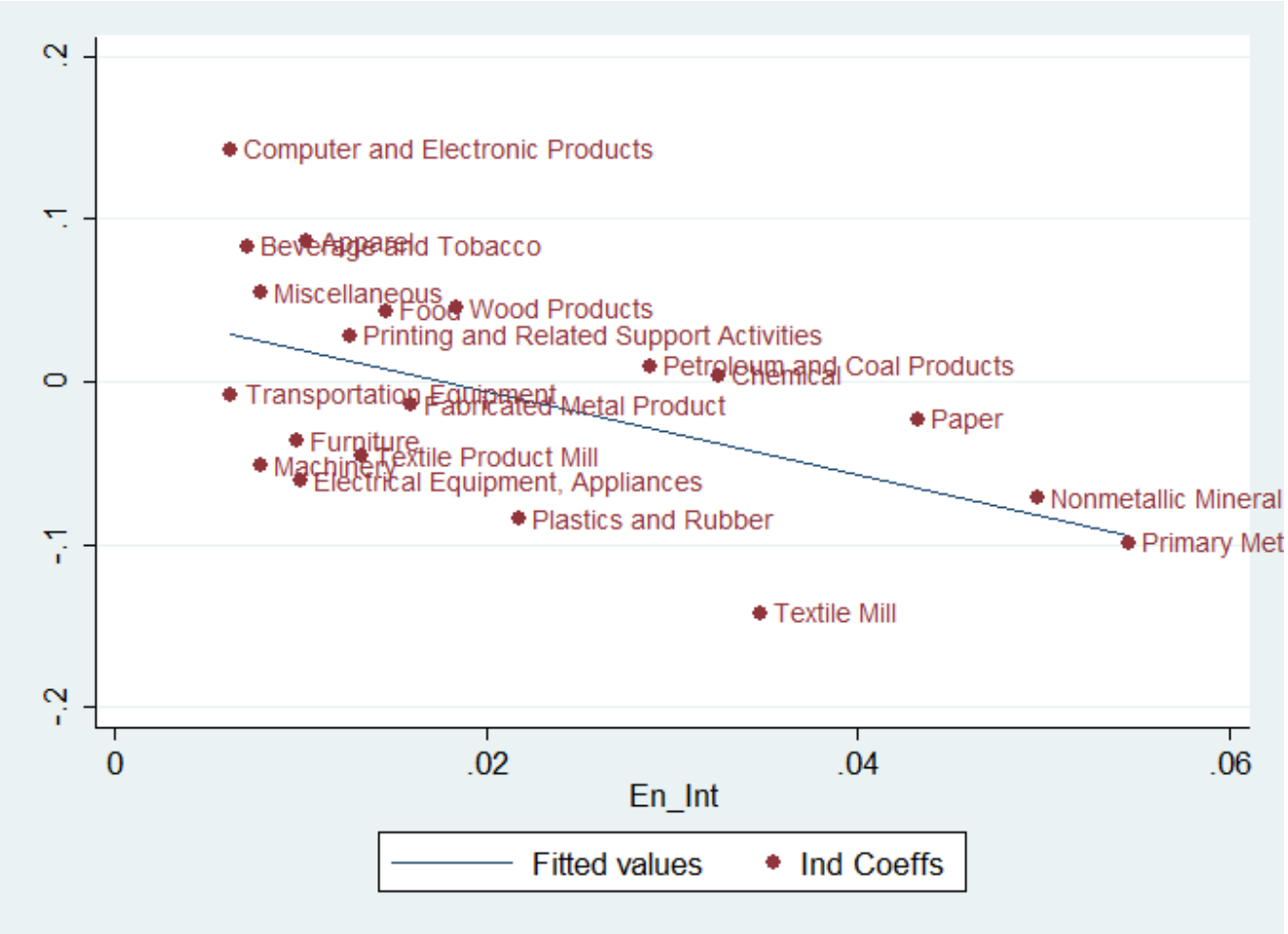
Regression Results: Imputing Missing Values

	1	2	3	4	5	6
		(IndxYear FE)	(CtyxYear FE)	(CtyxInd FE)	(CtyxInd FE)	(CtyxInd FE)
VARIABLES	lemp	lemp	lemp	lemp	lemp	lemp
PostxEastxInt	-2.107***	-2.149	-2.163***	-1.292 ***	-1.191**	-.6295
	(0.5051)	(2.056)	(0.6615)	(0.4670)	(0.458)	(0.438)
PostxEast	-.0239**	-.0142	.	-.0325***	.0207**	-.0124
	(0.0119)	(0.0482)		(0.0113)	(0.0098)	(0.0096)
Cty FE	Yes	Yes				
Ind FE	Yes		Yes			
Year FE	Yes			Yes	Yes	Yes
NAAQS Controls				Yes	Yes	Yes
Cty Trend					Yes	Yes
Ind Trend					Yes	
E/W Ind Trends						Yes
Observations	422,701	422,701	422,701	422,701	422,701	422,701
R-squared	. 4567	. 4593	. 4684	. 9140	. 9193	. 9191

Standard Errors are Robust to heteroskedasticity and are clustered at the county-industry level. The dependent variable is the ln(employment+1)

Plotting Industry Coefficients

$$lemp_{ckt} = \beta_1(Post_{ct}xEast_cxInd1_k) + ... + \beta_{21}(Post_{ct}xEast_cxInd21_k) + \\ + \delta_{ck} + \gamma_{ct} + \alpha_{kt} + \varepsilon_{ckt}$$



Discussion

- Employment in industries with an additional percentage point in energy intensity decreased by 1% in the region impacted by the NBP
- Employment Loss = $\sum_{k=1}^{K} (Empeast_k \; x \; EnInt_k \; x \; 1\%) = 101{,}841$
- Context
  - Total Manufacturing job loss in East 1998-2009: 3.2 Million
  - Greenstone: 590,000 jobs lost from NAAQS
  - Walker: 200,000 jobs lost implies from 1990 CAAA $9 billion of costs

Thank You

Basic Employment Diff-in-Diff by Industry Grouping

High Energy Industries

	Before	After	Diff
NBP	828.70	751.17	-77.53
Non-NBP Region	736.08	755.90	19.82
		Diff-in-Diff	-97.35

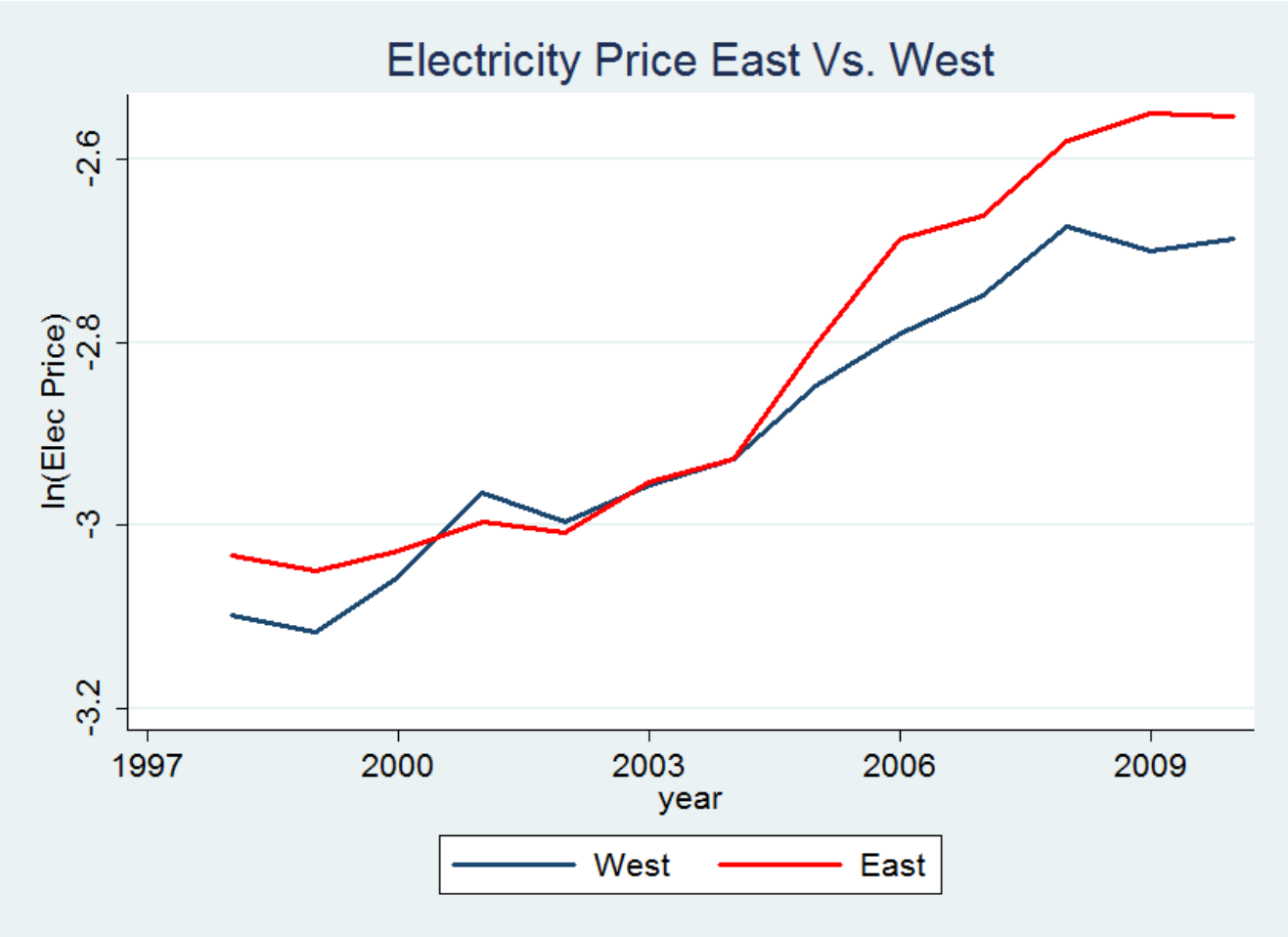
Medium Energy Industries

	Before	After	
NBP Region	788.59	777.68	-10.91
Non-NBP Region	816.85	868.21	51.36
		Diff-in-Diff	-62.26

Low Energy Industries

	Before	After	
NBP Region	1286.83	1187.95	-98.87
Non-NBP Region	1568.34	1447.06	-121.28
		Diff-in-Diff	22.41

Electricity Price Plot



Electricity Price Regressions

	(1)	(2)
VARIABLES	ln(ElecPrice)	ln(ElecPrice)
PostxEastxDereg		0.0892***
		(0.0337)
PostxEast	0.0642***	0.0195
	(0.0180)	(0.0246)
PostxDereg	0.0594***	0.0218
	(0.0174)	(0.0223)
Percoalxcoalprice	0.0133*	0.0127*
	(0.00679)	(0.00675)
Peroilxoilprice	0.0102***	0.00967***
	(0.00143)	(0.00143)
Pernatgasxnatgasprice	0.0740***	0.0763***
	(0.0154)	(0.0153)
Constant	-3.024***	-3.004***
	(0.109)	(0.109)
Observations	540	540
R-squared	0.946	0.947
State FE	YES	YES
Year FE	YES	YES

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1