International Environmental Agreement and Trade in Environmental Goods: The Case of Kyoto Protocol

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Motivation

Environmental regulation and competitiveness (Dechezlepretre and Sato, 2017)

- Pollution haven hypothesis
- Porter hypothesis

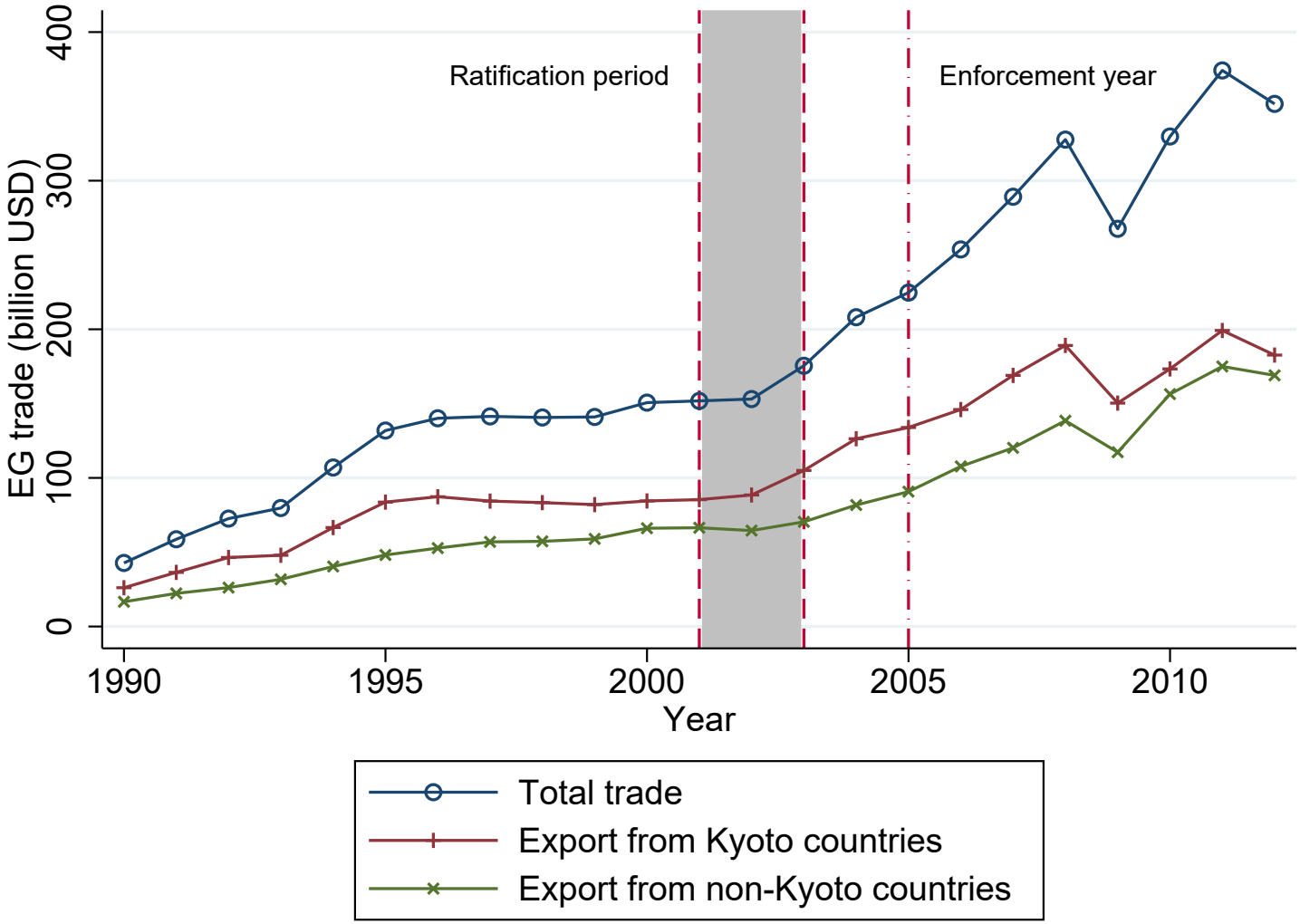
The Kyoto Protocol (KP)

- Adopted in 1997, entered into force in 2005
- Target: reduce the greenhouse gas (GHG) emission
- It is a controversial international treaty
  - Received lots of criticism
  - Empirical studies provided supporting evidence for its success (Aichele & Felbermayr, 2013a; Grunewald & Martinez-Zarzoso, 2016; Maamoun, 2019, JEEM)
  - Others showed evidence of carbon leakage and competitiveness loss resulting from the KP (Aichele & Felbermayr, 2012, JEEM; 2013b; 2015, RES)

Environmental Goods and Services Industry

- Activities which produce goods and services to **measure, prevent, limit, minimize** or **correct** environmental damage to water, air, and soil as well as problems related to waste noise and eco-systems (OECD/Eurostat, 1999)
- Categorized into 3 groups (OECD/Eurostat, 1999)
  - Pollution Management
  - Cleaner Technology and Products
  - Resource Management Example
- Importance of facilitating trade in environmental goods and services has been recognized by international communities
  - The Ministerial Declaration of the WTO Doha Round in 2001
  - 2012 Rio +20 outcome document "The Future We Want"

Trade trend during 1990–2012



Research Question

To what extent does the Kyoto Protocol affect export of environmental goods (EGs)?

Literature Review

Studies about the trade flow of environmentally friendly products are scant

- Environmental regulation as a driver of export of renewable energy technology (Costantini and Crespi, 2008)
- A strong positive correlation between the KP and trade in solar and wind technology (Miyamoto and Takeuchi, 2018)

Contributions

1. Provide the first evidence of the positive trade effect of the KP
2. Introduce the generalized synthetic control in the gravity model context

Generalized synthetic control (GSC) by Xu (2017)

- Based on SCM by Abadie et al. (2010, 2015)
- Integrates the interactive fixed effects (IFE) model (Bai, 2009, Econometrica)
- Advantages
  1. Allow the analysis on multiple treated units
  2. Provide classical standard errors to infer statistical significance

Empirical framework

$$Y_{pt} = \alpha_{pt} Kyoto_{pt} + \beta x'_{pt} + \lambda'_p f_t + \varepsilon_{pt} \quad (1)$$

where Y_{pt}: trade value of an exporter-importer pair p in year t

$Kyoto_{pt}$: 1 if the exporter of a country pair p has a Kyoto commitment in year t and 0 otherwise

x'_{pt}: a vector of observed covariates, including GDP, FTA membership, common currency membership

α_{pt}: the heterogeneous treatment effect on country pair p in year t

f_t: a vector of unobserved common factors

λ_p: a vector of unknown factor loadings

Estimation of ATT

- $Y_{pt}(1) = \alpha_{pt} + \beta x'_{pt} + \lambda'_p f_t + \varepsilon_{pt}$
- $Y_{pt}(0) = \beta x'_{pt} + \lambda'_p f_t + \varepsilon_{pt}$
- The treatment effect on the treated pair p in year t:

$$\alpha_{pt} = Y_{pt}(1) - Y_{pt}(0), t > T_0$$

- The average treatment effect on the treated (ATT):

$$ATT_t = \frac{1}{N_{tr}} \sum_{i \in \mathcal{T}} \alpha_{pt}$$

- Core idea of the GSC: estimate the counterfactual of the treated pairs $Y_{pt}(0)$ Detail

Data

- Bilateral trade data at the product level from 1990–2015 (UN Comtrade, 2018)
- Sample of analysis:
  - Analysis period: 1990–2012
  - Include 136 exporters and 95 importers
    - Total: 3,932 country pairs
    - 1,790 country pairs have the Kyoto commitments (45.5%)
  - # EGs: 86 products
    - Exclude waste management goods, noise abatement goods etc.
  - Treatment period: Ratification years Details

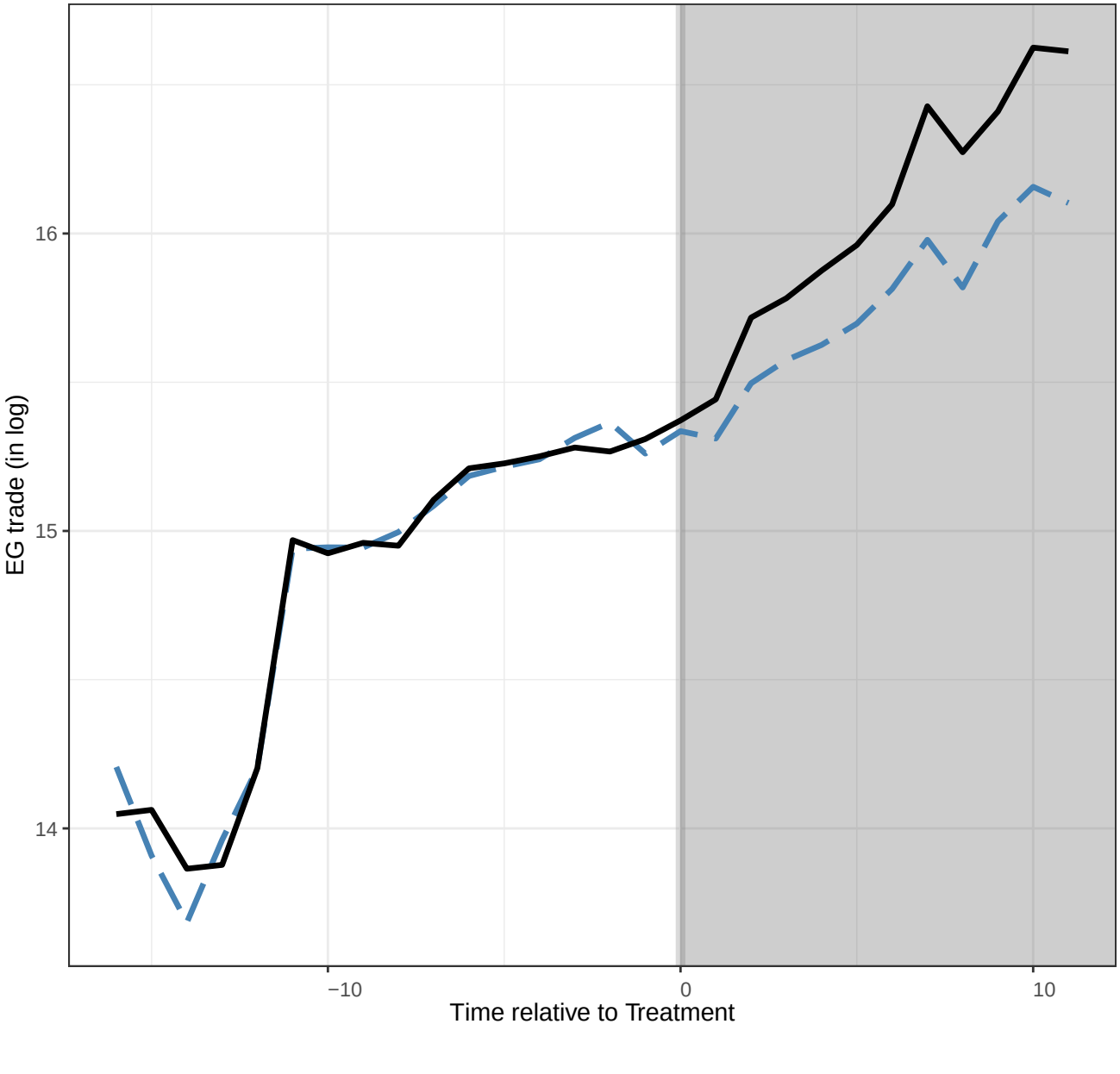
Main Result

Coefficient/ATT	Baseline	Add. cov.
Kyoto dummy	0.320***	0.314***
	(0.065)	(0.069)
Ln(GDP Exporter)	1.629***	1.995***
	(0.143)	(0.244)
Ln(GDP Importer)	1.280***	1.135***
	(0.147)	(0.320)
MSPE	0.761	0.760
No. treated	895	895
No. control	2,142	2,142
Unobserved factors	1	1

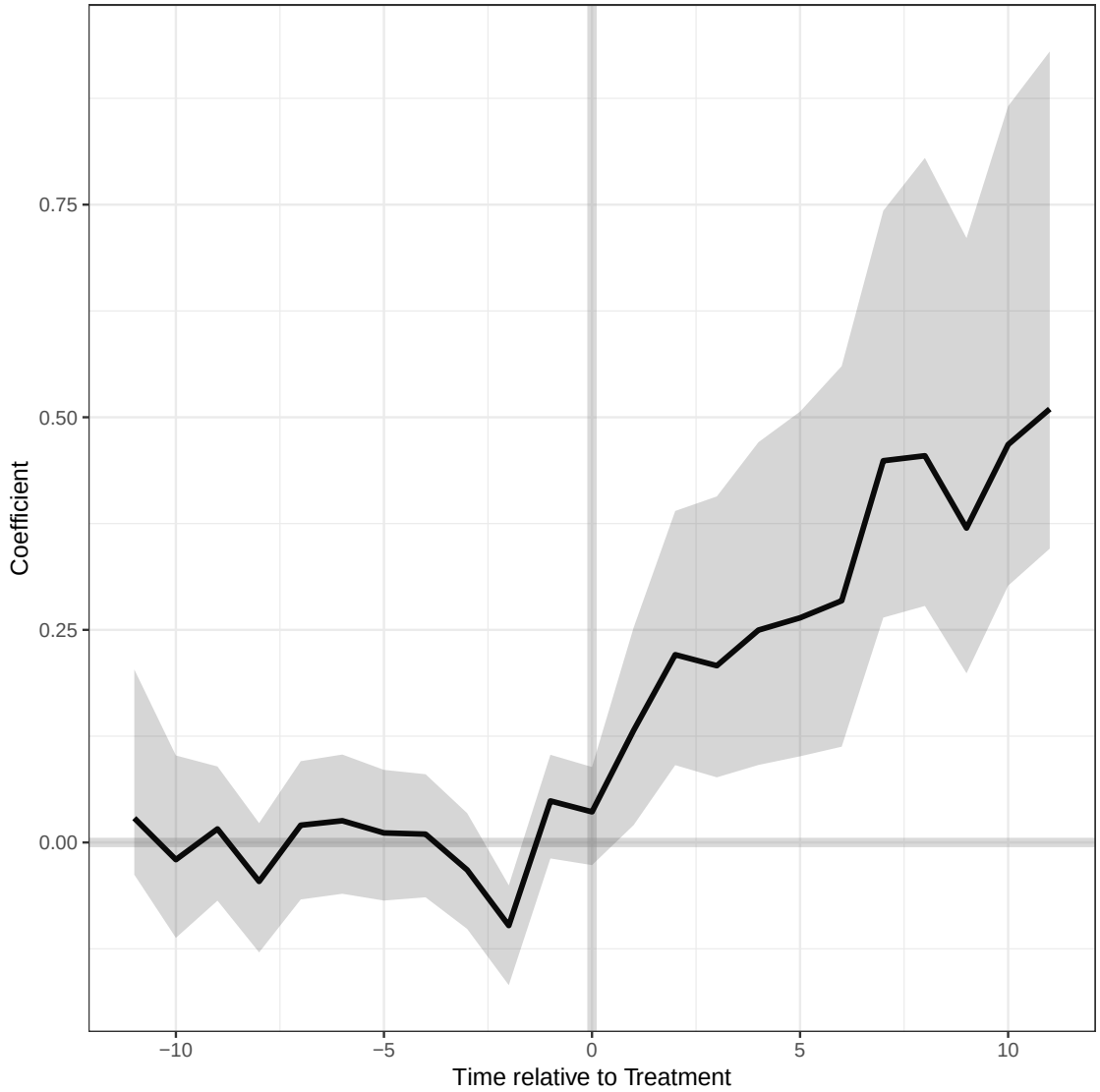
Notes. Standard errors, in parentheses, are based on parametric bootstraps of 1000 times. *** Significance at 1%

ROU graphs RC

Main Result: Treated and Counterfactual Average



Main Result: Estimated ATT



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Robustness Check

- Different treatment period: Enforcement year
- Different analysis period:
  - 1990–2015
  - 1992–2012
- Only export to non-Kyoto countries
- Canada: treated country
- Exclusion of top exporter (USA, DEU)

Conclusion

- The first paper to provide evidence of the Kyoto Protocol's positive trade effect
  - The exports of EGs increase by 32% compared to the "no-Kyoto" scenario
  - The Kyoto Protocol is a source of comparative advantage in EG production
- The results provide optimistic view about the international cooperation

Thank you

Comments? Questions?

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EG example

main

Annex B countries and ratification year

Australia - 2007	Austria - 2002	Belgium - 2002	Bulgaria - 2002
Czech Republic - 2001	Croatia - 2007	Denmark - 2002	Estonia - 2002
Finland - 2002	France - 2002	Germany - 2002	Greece - 2002
Hungary - 2002	Iceland - 2002	Ireland - 2002	Italy - 2002
Japan - 2002	Latvia - 2002	Lithuiana - 2003	Luxembourg - 2002
Netherlands - 2002	New Zealand - 2002	Norway - 2002	Poland - 2002
Portugal - 2002	Romania - 2001	Russia - 2004	Slovakia - 2002
Slovenia - 2002	Spain - 2002	Sweden - 2002	Switzerland - 2003
Ukraine - 2002	United Kingdom - 2002		

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Estimation of counterfactuals $\hat{Y_{pt}}(0)$

- Number of country pairs: $N = N_{tr} + N_{co}$
- The outcome of a pair from the control group can be written as

$$Y_{pt} = X'_{pt}\beta + \lambda'_p f_t + \varepsilon_{pt}$$

- The outcome of the counterfactual after the combination of all control pairs is

$$Y_{co} = X_{co}\beta + F\Lambda'_{co} + \varepsilon_{co}$$

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Estimation of counterfactuals $\hat{Y_{pt}}(0)$

- Step 1: estimate an IFE model using the control group data and obtain $\hat{\beta}$, $\hat{F}$, $\hat{\Lambda_{co}}$

$$(\hat{\beta}, \hat{F}, \hat{\Lambda_{co}}) = \text{argmin}_{\tilde{\beta}\tilde{F}\tilde{\Lambda_{co}}} \sum_{p \in C} (Y_p - X_p\tilde{\beta} - \tilde{F}\tilde{\lambda_p})'(Y_p - X_p\tilde{\beta} - \tilde{F}\tilde{\lambda_p})$$

s.t. $\tilde{F}'\tilde{F}/T = I_r$ and $\tilde{\Lambda_{co}}'\tilde{\Lambda_{co}} =$ diagonal

- Step 2: estimate factor loadings for each treated unit

$$\hat{\lambda_p} = \text{argmin}_{\tilde{\lambda_p}} (Y_p^0 - X_p^0\hat{\beta} - \hat{F^0}\tilde{\lambda_p})'(Y_p^0 - X_p^0\hat{\beta} - \hat{F^0}\tilde{\lambda_p})$$

$$= (\hat{F^0}'\hat{F^0})^{-1}\hat{F^0}'(Y_p^0 - X_p^0\hat{\beta}), p \in \mathcal{T}$$

- Step 3: calculate treated counterfactuals based on $\hat{\beta}$, $\hat{F}$, $\hat{\lambda_p}$:

$$\hat{Y_{pt}^0} = x_{pt}'\hat{\beta} + \hat{\lambda_p}'\hat{f_t}$$

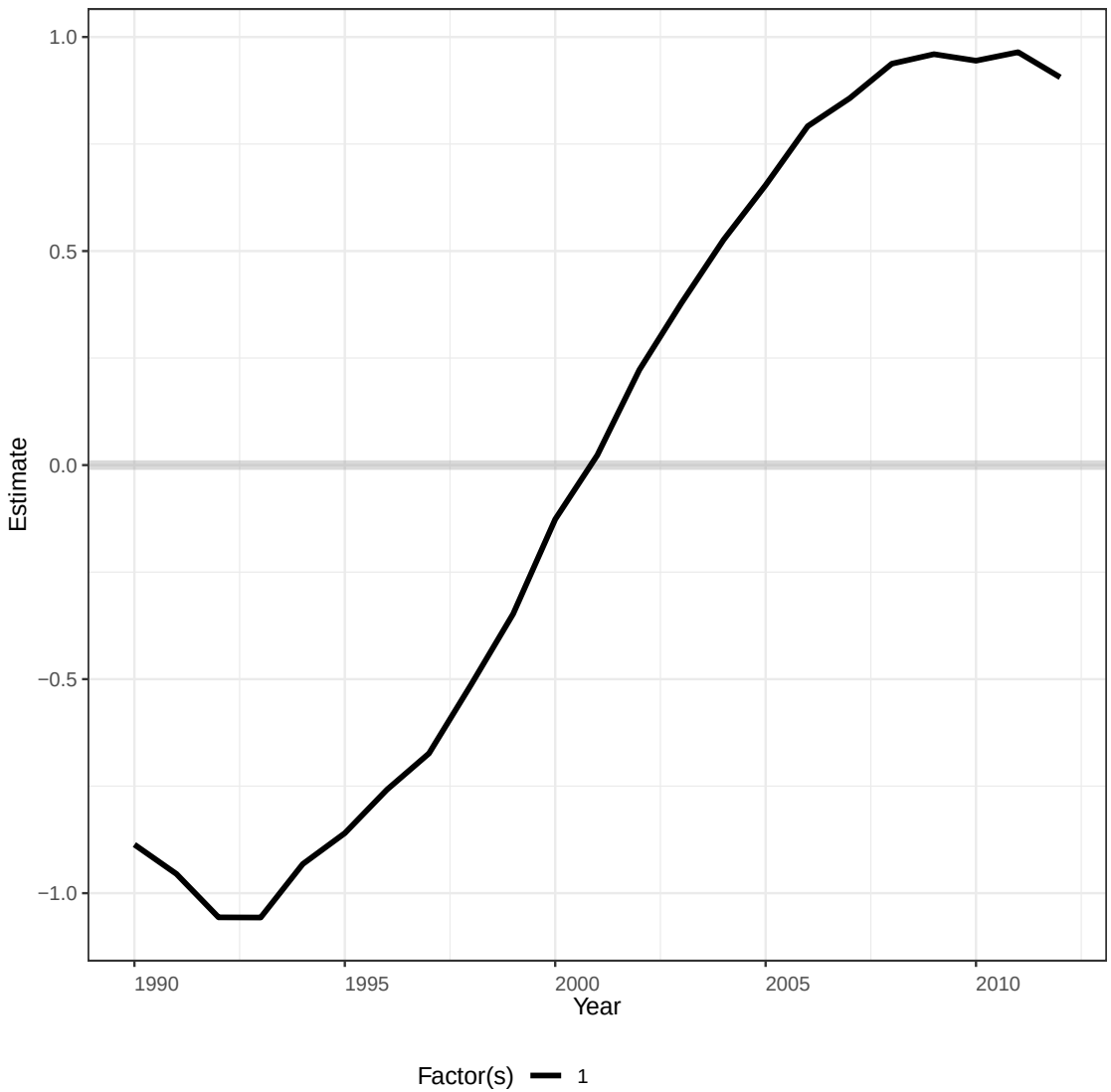
$$p \in \mathcal{T}, t > T_0$$

$\hat{ATT_t} = \frac{1}{N_{tr}} \sum_{i \in \mathcal{T}} [Y_{pt}(1) - \hat{Y_{pt}}(0)]$ for $t > T_0$ main

Summary Statistics

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Ln(Trade)	90,848	14.20	3.143	0.723	22.96
Kyoto dummy	90,848	0.214	0.410	0	1
Ln(GDP Exporter)	90,848	26.48	1.760	19.18	30.44
Ln(GDP Importer)	90,848	25.99	2.080	19.83	30.44
Ln(GDPC Exporter)	90,848	9.542	1.284	5.087	11.43
Ln(GDPC Importer)	90,848	9.246	1.411	5.208	11.43
RTA	90,848	0.251	0.433	0	1
Common Currency	90,848	0.0273	0.163	0	1
Energy intensity	90,848	-0.000219	4.354	-31.46	46.60
EU	90,848	0.0646	0.246	0	1
WTO	90,848	0.842	0.365	0	1

Factor


1.0
0.5
0.0
−0.5
−1.0
Estimate
1990
1995
2000
2005
2010
Year
Factor(s) 1

Robustness Check

	(1)	(2)	(3)	(4)
ATT	0.188***	0.448***	0.320***	0.337***
	(0.041)	(0.076)	(0.100)	(0.069)
Ln(GDP_{it})	1.629***	1.747***	1.974***	1.597***
	(0.141)	(0.121)	(0.178)	(0.142)
Ln(GDP_{jt})	1.280***	1.302***	1.258***	1.295***
	(0.145)	(0.132)	(0.202)	(0.156)
FTA_{pt}	0.076	0.063	-0.105	0.071
	(0.047)	(0.042)	(0.064)	(0.048)
$Currency_{pt}$	1.034***	0.803***	-2.253	1.034***
	(0.195)	(0.210)	(6.490)	(0.200)
MSPE	0.818	0.761	0.873	0.751
No. treated	1,619	895	568	937
No. control	2,142	2,142	1,231	2,058
Unobserved factors	1	1	1	1

Notes. Standard errors, in parentheses, are based on parametric bootstraps of 1000 times unless noted. ***, **, * Significance at 1%, 5%, and 10%.
(1) Treatment period: Enforcement year
(2) The sample period is 1990–2015
(3) Only trade to non-Kyoto countries are analyzed
(4) Canada is included in the treated group

Robustness Check (cont.)

	(5)	(6)	(7)
ATT	0.375***	0.310***	0.308***
	(0.069)	(0.072)	(0.071)
Ln(GDP_{it})	1.646***	1.514***	1.629***
	(0.156)	(0.147)	(0.141)
Ln(GDP_{jt})	1.319***	1.313***	1.280***
	(0.154)	(0.159)	(0.149)
FTA_{pt}	0.061	0.069	0.076
	(0.049)	(0.046)	(0.048)
$Currency_{pt}$	1.023***	1.000***	1.034***
	(0.198)	(0.195)	(0.203)
MSPE	0.738	0.761	0.786
No. treated	852	895	853
No. control	2,142	2,049	2,142
Unobserved factors	1	1	1

Notes. Standard errors, in parentheses, are based on parametric bootstraps of 1000 times unless noted. ***, **, * Significance at 1%, 5%, and 10%.
(5) The sample period is 1992–2012
(6) The sample excludes USA as exporter
(7) The sample excludes DEU as exporter

Robustness Check

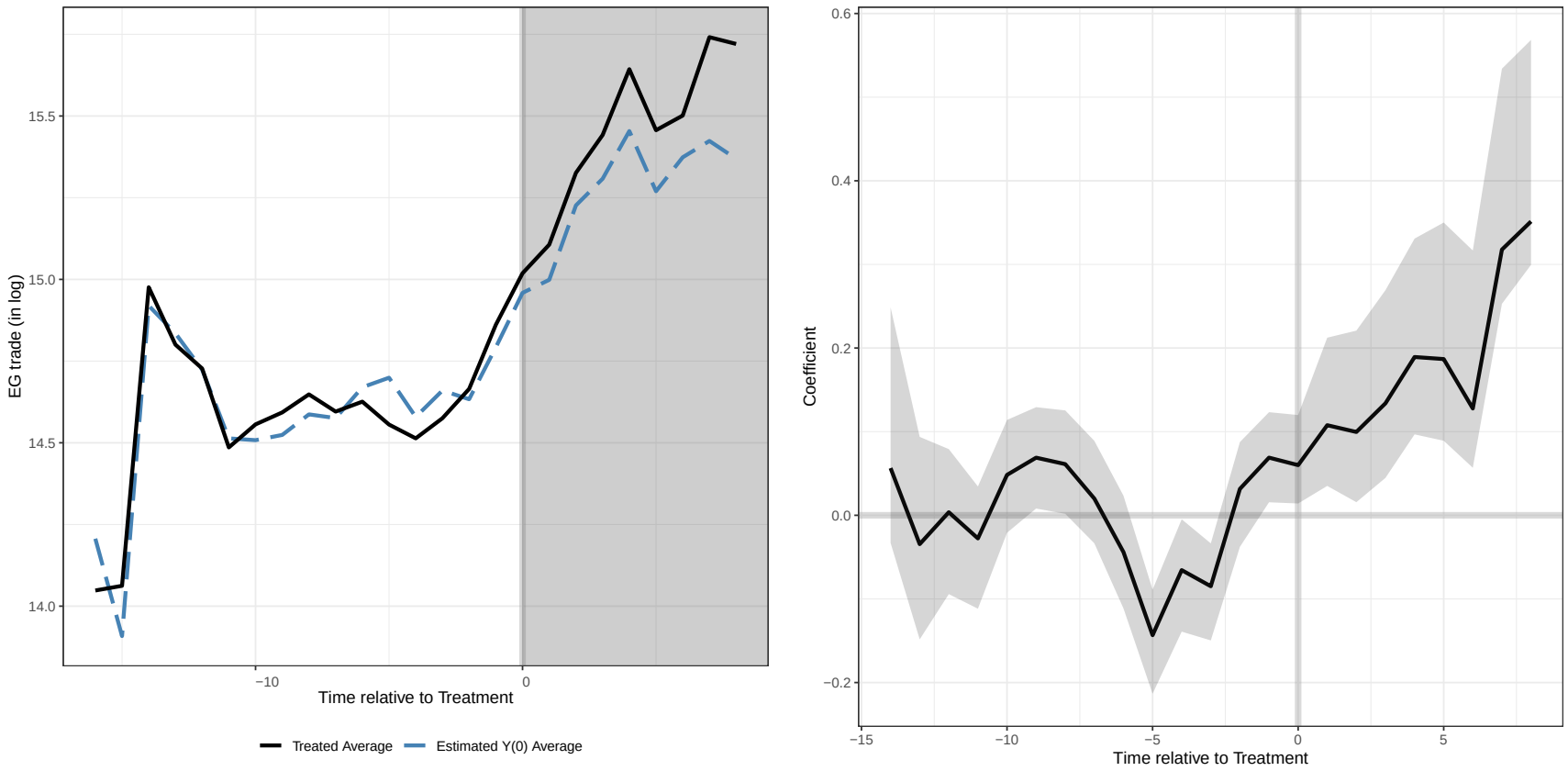
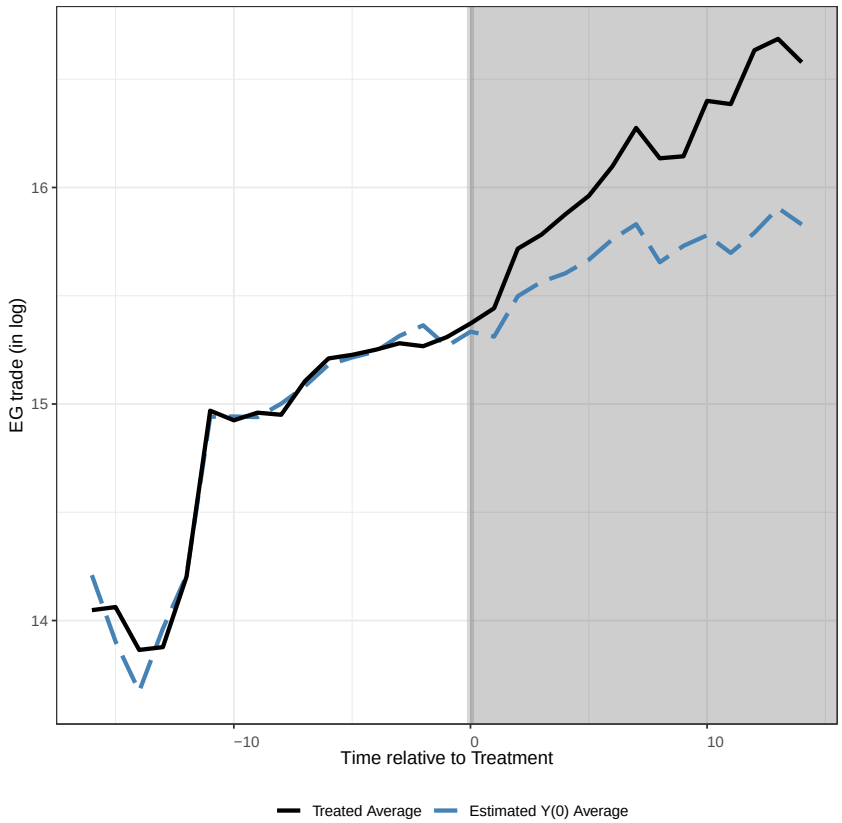


Figure: Treatment period: Enforcement year

Robustness Check



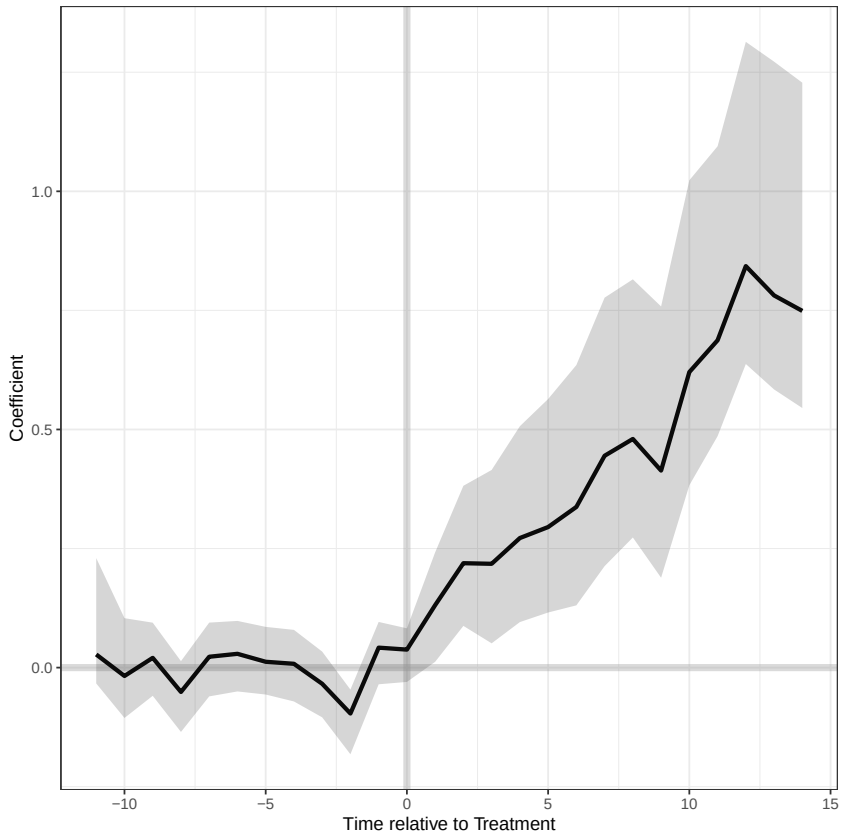


Figure: Sample period: 1990–2015

More RC-2

Robustness Check

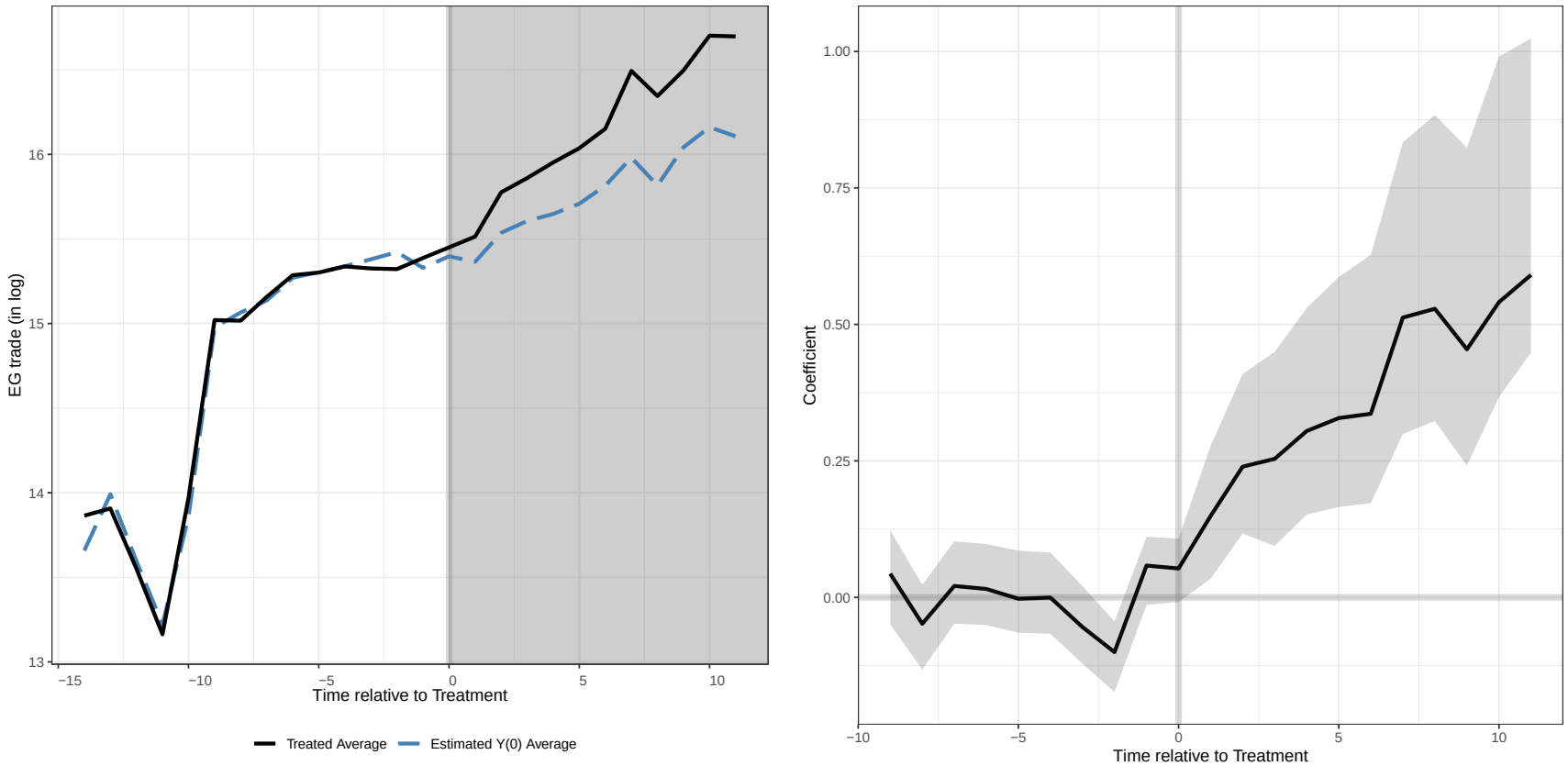


Figure: Period analysis: 1992–2012

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Robustness Check

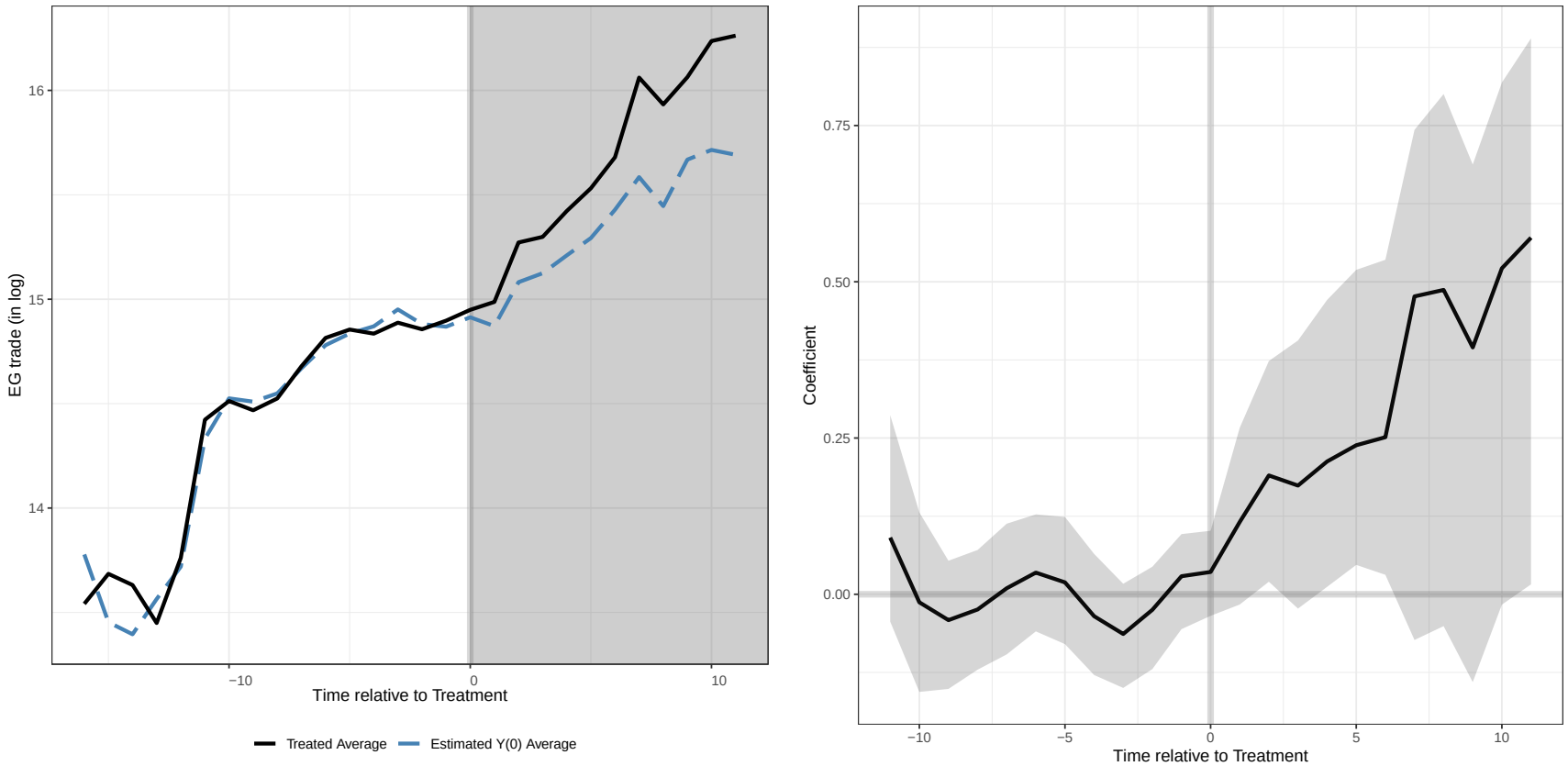

Figure: Restricted sample: trade to non-Kyoto countries only

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Robustness Check

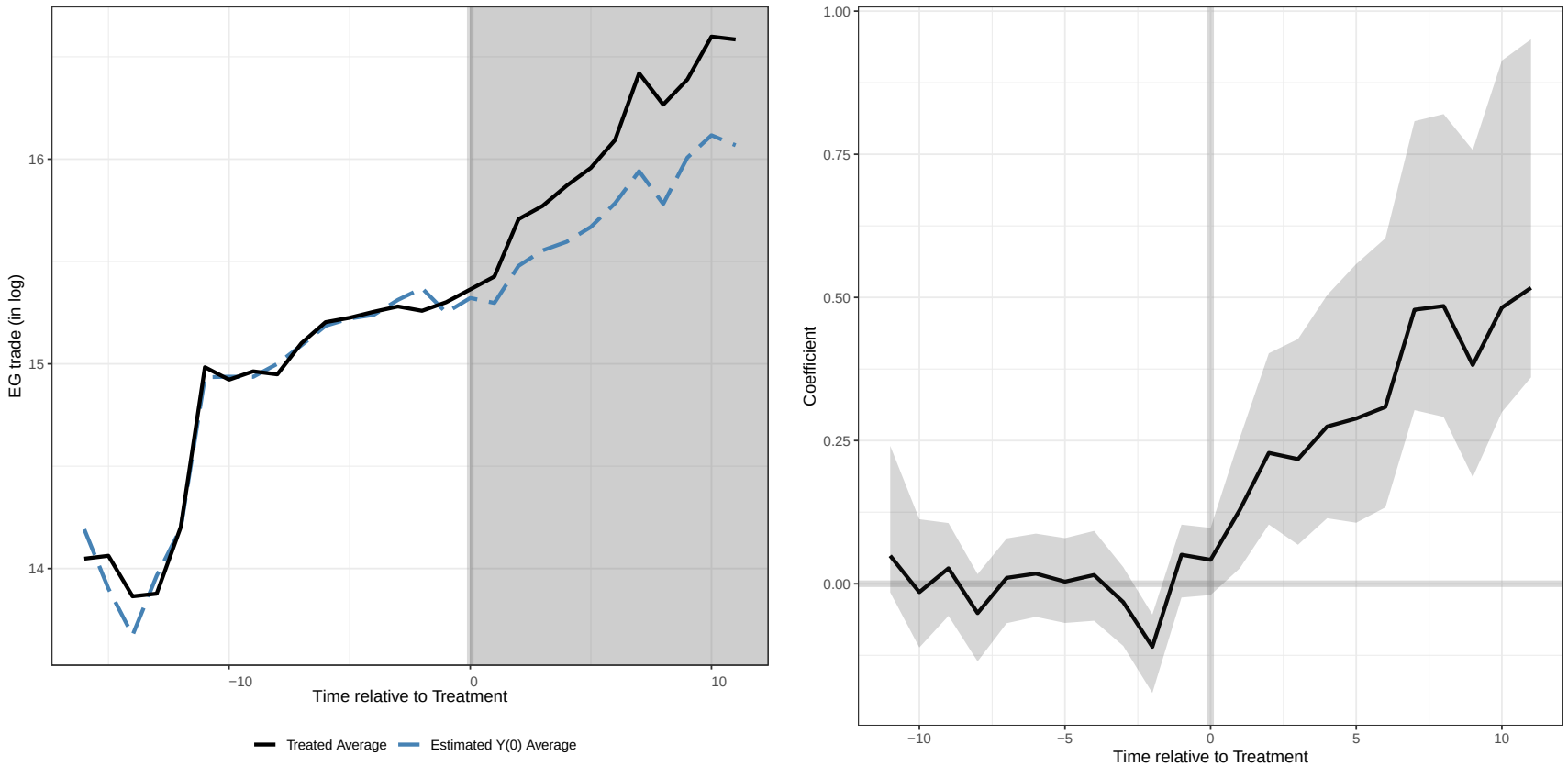

Figure: Canada is in the treated group

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Robustness Check

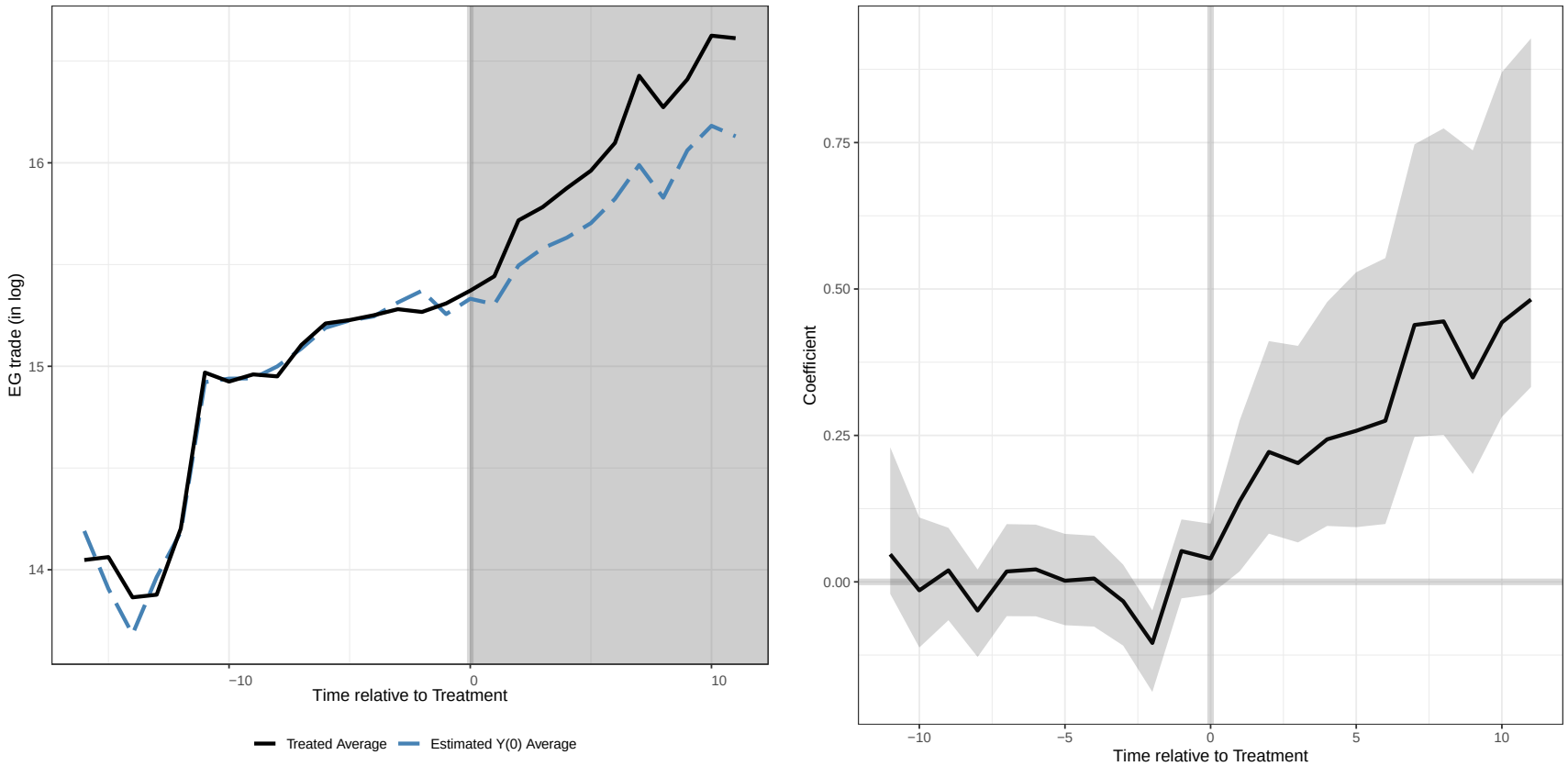

Figure: Exclusion of USA as an exporter

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Robustness Check

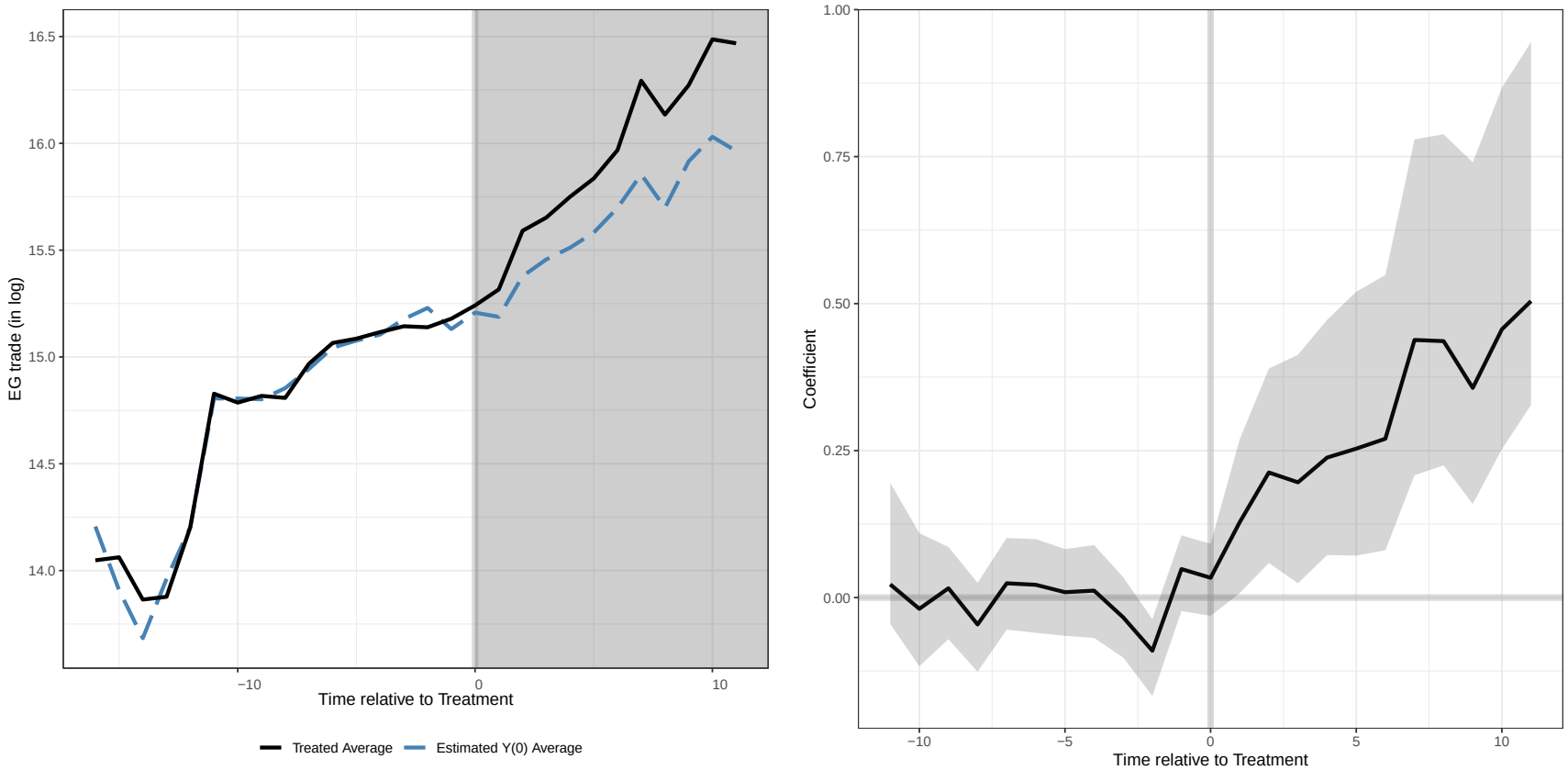

Figure: Exclusion of Germany as an exporter

main

Comparison to PSM-DID

- Following the PSM-DID method as in Aichele & Felbermayr (2013b)
- Using averages of two periods: pre- and post-treatment
  - Pre: 1997–2000 & post: 2004–2007
  - Propensity score is estimated as

$$Prob(Kyoto_{p0} = 1) = \Phi(GDP_{p,-1}, GDPC_{p,-1}, Population_{p,-1}, Eintensity_{p,-1}) \quad (2)$$

  - Matching: nearest neighbor matching, kernel matching and Mahalanobis matching Balancing test
  - DID is carried out as

$$Y_{ps} = \beta_0 + \beta_{ps} Kyoto_{ps} + \gamma x'_{ps} + \alpha_p + \alpha_s + \epsilon_{ps} \quad (3)$$

Balancing property

	Unmatched sample			Matched sample		
	Control	Treated	Diff.	Control	Treated	Diff.
Joint GDP	51.730	51.963	0.233***	51.908	51.979	0.070
	(2.443)	(2.210)	(0.001)	(2.454)	(2.198)	(0.323)
Joint GDPC	-0.287	0.730	1.018***	0.719	0.723	0.004
	(1.806)	(1.480)	(0.000)	(1.516)	(1.483)	(0.932)
Joint population	18.093	17.542	-0.551***	17.538	17.568	0.029
	(1.388)	(1.148)	(0.000)	(1.259)	(1.130)	(0.421)
Energy intensity	0.055	-0.239	-0.294*	-0.098	-0.252	-0.154
	(4.922)	(5.490)	(0.057)	(4.138)	(5.503)	(0.299)
Observations	2,424	2,200	4,624	2,063	2,146	4,209

Notes. Matching type is nearest neighbor matching with 5 neighbors. Column "Control" and "Treated" show mean and S.D of variables in the control group and the treated group. p-value of t-test is in parentheses of column "Diff."

main

Comparison to PSM-DID

VARIABLES	(1) NN 5	(2) NN 5	(3) Kernel	(4) Kernel	(5) Maha5	(6) Maha5
$Kyoto_{ps}$	0.392***	0.037	0.407***	0.037	0.479***	0.028
	(0.063)	(0.066)	(0.059)	(0.061)	(0.067)	(0.071)
GDP Exporter	0.989***	2.352***	1.002***	2.293***	1.043***	2.257***
	(0.021)	(0.318)	(0.018)	(0.294)	(0.021)	(0.379)
GDP Importer	0.710***	1.005***	0.726***	1.028***	0.785***	1.153***
	(0.017)	(0.221)	(0.015)	(0.209)	(0.016)	(0.224)
Observations	8,416	8,416	8,960	8,960	7,926	7,926
R-squared	0.576	0.952	0.582	0.952	0.586	0.952
Country pair FE	No	Yes	No	Yes	No	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1