


The Carbon Content of International Trade: Effects of the Kyoto Protocol

Gabriel Felbermayr

LMU München und ifo Institut

FIW-Workshop

Trade and Environment

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TRADE AND CLIMATE POLICY

FACT 1: World merchandise imports over GDP: 25% and growing

FACT 2: No world-wide price for carbon, no world-wide carbon emission cap

⇒ Heterogeneous carbon policies (taxes, standards, caps, ...) give rise to concerns about

- International competitiveness
- Environmental efficiency (carbon leakage)

CARBON LEAKAGE

Special case of ***pollution haven hypothesis***

- Heterogeneous (e.g. unilateral) climate policies change patterns of *comparative advantage* and lead to *relocation* of CO_2-intensive production
  - Potential implications for all factor prices and threat of deindustrialization
  - Emission reductions in 'green' countries may be (more than) offset by higher emissions in 'brown' countries

$\Rightarrow$ Call for ***border adjustment taxes*** (BAT)

(Sarkozy, Macron, Krugman, Waxman-Markey bill, ...)

26 YEARS OF CLIMATE DIPLOMACY

- 1992: Earth Summit, Rio de Janeiro. UN-FCCC established
  - Principle of "***common but differentiated responsibility***"
  - Voluntary limitations of national CO2-emissions
- 1997: Members of UN-FCCC conclude the **Kyoto-Protocol**
  - Binding CO2 emission targets: 5.2% below 1990 levels until 2012
  - Rules on trade of emission permits and compensation
  - 2002-2003 Countries ratify Kyoto (not US!)
  - 2005: entry into force
- 2012: Doha Amendment – prolongation of Kyoto to 2020
- 2015: **Paris Agreement**
- 2017: President Trump announces that US withdraw from Paris Agreement

LEARNING FROM KYOTO FOR THE FUTURE

(probably)

QUESTION 1: Was the Kyoto Protocol effective after all ? [A&F: JPAM 2013] **YES**

QUESTION 2: Did Kyoto commitment lower the carbon footprint of nations ? [A&F: JEEM 2012] **NO**

QUESTION 3: Have Kyoto commitments led to carbon leakage ? [A&F: REStat, 2015] **NO**

⇒ **Border Adjustment Tax (≠ carbon tariff !) would make sense**

1. Instrument to foster coalition stability
2. and to improve efficiency of carbon policies

AGENDA

- Introduction
- **Effectiveness of Kyoto**
- Kyoto and the CO2 Footprint of Nations
- Kyoto and Carbon leakage

ECONOMETRIC APPROACH

¶ Second-stage regressions

$$Y_{it} = \beta_0 + \beta_1 Kyoto_{it} + \beta_2 \mathbf{X}'_{it} + \alpha_t + \alpha_i + \varepsilon_{it}$$

$$Kyoto_{it} = \begin{cases} 1 \text{ ratification of emission cap and } t \geq \text{ ratification year,} \\ 0 \qquad\qquad\qquad\qquad\qquad\qquad \text{else.} \end{cases}$$

- Pre-treatment period: 1995-2000
- Post-treatment period: 2004-2007

¶ First-stage regressions

$$Kyoto_{it} = \alpha + \gamma \mathbf{X}'_{it} + \zeta \mathbf{Z}'_{it} + \nu_i + \nu_t + \upsilon_{it}$$

KYOTO AND ICC MEMBERSHIP

in a large panel of countries (N=133)

Dependent variable: Kyoto commitment (0,1)					
	Linear probability				Probit long
	FE			Long FE	diff.[a]
Model / Method	(1)	(2)	(3)	(4)	(5)
Excluded instruments					
ICC (0,1)	0.19***	0.11***	0.10***	0.25***	0.16***
	(0.05)	(0.04)	(0.03)	(0.07)	(0.03)
ICC, spatial lag		0.51***	0.41***	0.37***	0.04***
		(0.10)	(0.08)	(0.12)	(0.01)
Other controls			yes	yes	yes
No. of observations	1,456	1,456	1,418	266	133
Adj. R^2	0.25	0.52	0.61	0.69	

Other controls: ln GDP (-), ln GDP squared (+), ln population (-), ln manuf. in % of GDP), ln agriculture in % of GDP (-), ln services in% GDP (+), ln stock of other IEA, Government orientation , Openness (-), WTO (-), Polity (–).

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KYOTO AND CO2 EMISSIONS

Dependent variable: ln CO_2 emissions					
Method	FE-OLS (1)	FE-OLS (2)	FE-IV (3)	Long FE-OLS (4)	Long FE-IV (5)
Kyoto (0,1)	−0.17***	−0.06**	−0.10**	−0.09**	−0.12*
	(0.03)	(0.02)	(0.05)	(0.04)	(0.07)
Kyoto, spatial lag		0.01**	0.02***	0.03***	0.03***
		(0.01)	(0.00)	(0.01)	(0.01)
Other controls		yes	yes	yes	yes
No. of observations	1,456	1,418	1,418	266	266
No. of countries	133	133	133	133	133
First-stage diagnostics					
Shea's partial R^2			0.28		0.43
Hansen–Sargan J-stat (P-value)			0.44		0.71
Weak-ID test (F-stat)			19.09		37.70
Second-stage diagnostics					
Adj. R^2	0.27	0.48		0.49	
F-stat	11.99	13.85	17.44	21.40	23.09

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CHANNELS OF THE KYOTO EFFECT, I

Panel	(A) Shares in energy use				(B) Shares in electricity production			
Dep. var.	Renewables		Fossil fuel		Coal		Alternative energy	
Method	(A1) FE-OLS	(A2) FE-IV	(A3) FE-OLS	(A4) FE-IV	(B1) FE-OLS	(B2) FE-IV	(B3) FE-OLS	(B4) FE-IV
Kyoto (0,1)	1.38**	2.41***	−0.67	−2.46**	0.12	−1.43	1.07***	1.66***
	(0.56)	(0.93)	(0.63)	(1.16)	(0.93)	(1.76)	(0.27)	(0.56)
No. of observations	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180
No. of countries	110	110	110	110	110	110	110	110
Shea's partial R^2		0.26		0.26		0.26		0.26
Over-ID test (P-value)		0.68		0.47		0.60		0.63
Weak-ID test (F-stat)		18.80		18.80		18.80		18.80
Adj. R^2	0.29		0.17		0.06		0.17	

CHANNELS OF THE KYOTO EFFECT, II

Panel	(C) Pump prices (USD/L)				(D) Log per capita use of			
Dep. var.	Diesel fuel		Gasoline		Energy		Electricity	
Method	(C1) FE-OLS	(C2) FE-IV	(C3) FE-OLS	(C4) FE-IV	(D1) FE-OLS	(D2) FE-IV	(D3) FE-OLS	(D4) FE-IV
Kyoto (0,1)	0.10**	0.22***	0.13***	0.25***	−0.05**	−0.05*	−0.04	−0.08**
	(0.04)	(0.05)	(0.04)	(0.05)	(0.02)	(0.03)	(0.03)	(0.04)
No. of observations	608	608	608	608	1,180	1,180	1,169	1,169
No. of countries	127	127	127	127	110	110	109	109
Shea's partial R^2		0.28		0.28		0.26		0.26
Over-ID test (*P*-value)		0.61		0.32		0.36		0.21
Weak-ID test (*F*-stat)		20.30		20.30		18.80		18.84
Adj. R^2	0.77		0.68		0.38		0.52	

Kyoto did affect outcomes

despite lack of enforcement and despite incomplete

and second-best implementation

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TRADE AND CLIMATE POLICY

International Trade

- Territorial CO_2 emissions and emissions embodied in domestic absorption (consumption, investment) [= **CO_2 footprint**] can diverge
  - Patterns of comparative advantage
  - Climate policies (even reciprocal / symmetric ones!)
  - Trade policies
- Generally, changes in climate policies or trade policies will affect difference between territorial emissions and footprints of nations
- Here: Focus on **Kyoto-Protocol**

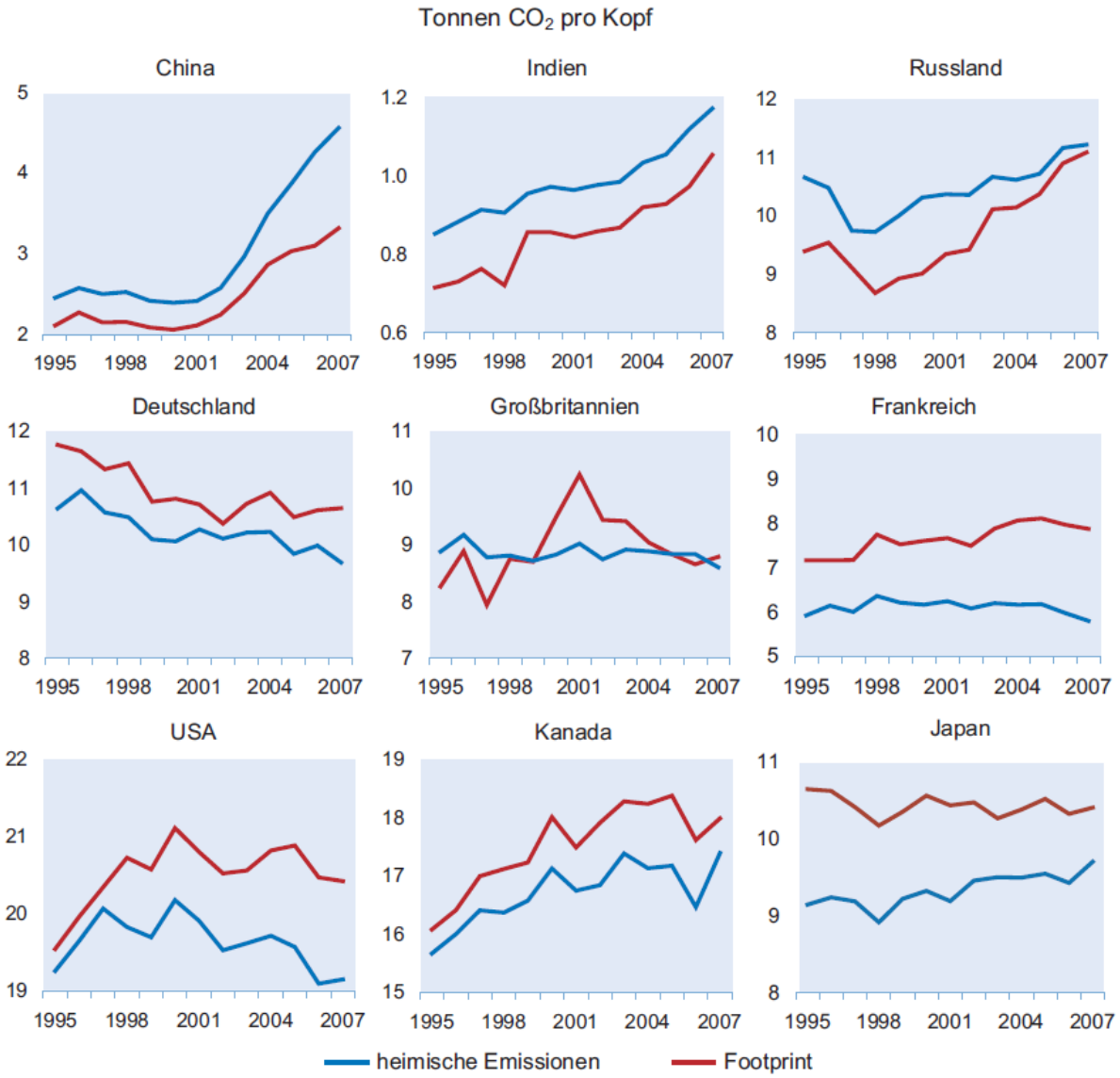
ESTIMATING CO_2 FOOTPRINTS

- Footprint F_{it} is the sum of territorial emissions E_{it} and emissions embodied in imports EET_{it}

$$F_{it} = E_{it} + EET_{it}$$

- Multi-region Input-Output (MRIO) table $\mathbf{B} \equiv [\boldsymbol{B_{ij}}]$, where $\boldsymbol{B_{ij}}$ are bilateral I-O tables capturing sectoral input usage links
- Sectoral emission intensity vectors $\boldsymbol{e_i}$, and $\boldsymbol{e} \equiv (\boldsymbol{e_1} \ldots \boldsymbol{e_N})$ for the world
- Vector of total carbon intensities $\boldsymbol{A} = \boldsymbol{e}(\boldsymbol{I} - \boldsymbol{B})^{-1}$
- Net emissions embodied in trade $EET_i = \boldsymbol{AT_i}$,where $\boldsymbol{T_i}$ is country i's net trade vector
- Implemented for 40 countries using OECD and UNIDO data

FOOTPRINTS &TERRITORIAL EMISSIONS



EMPIRICAL SETUP

¶ **Second stage** regressions

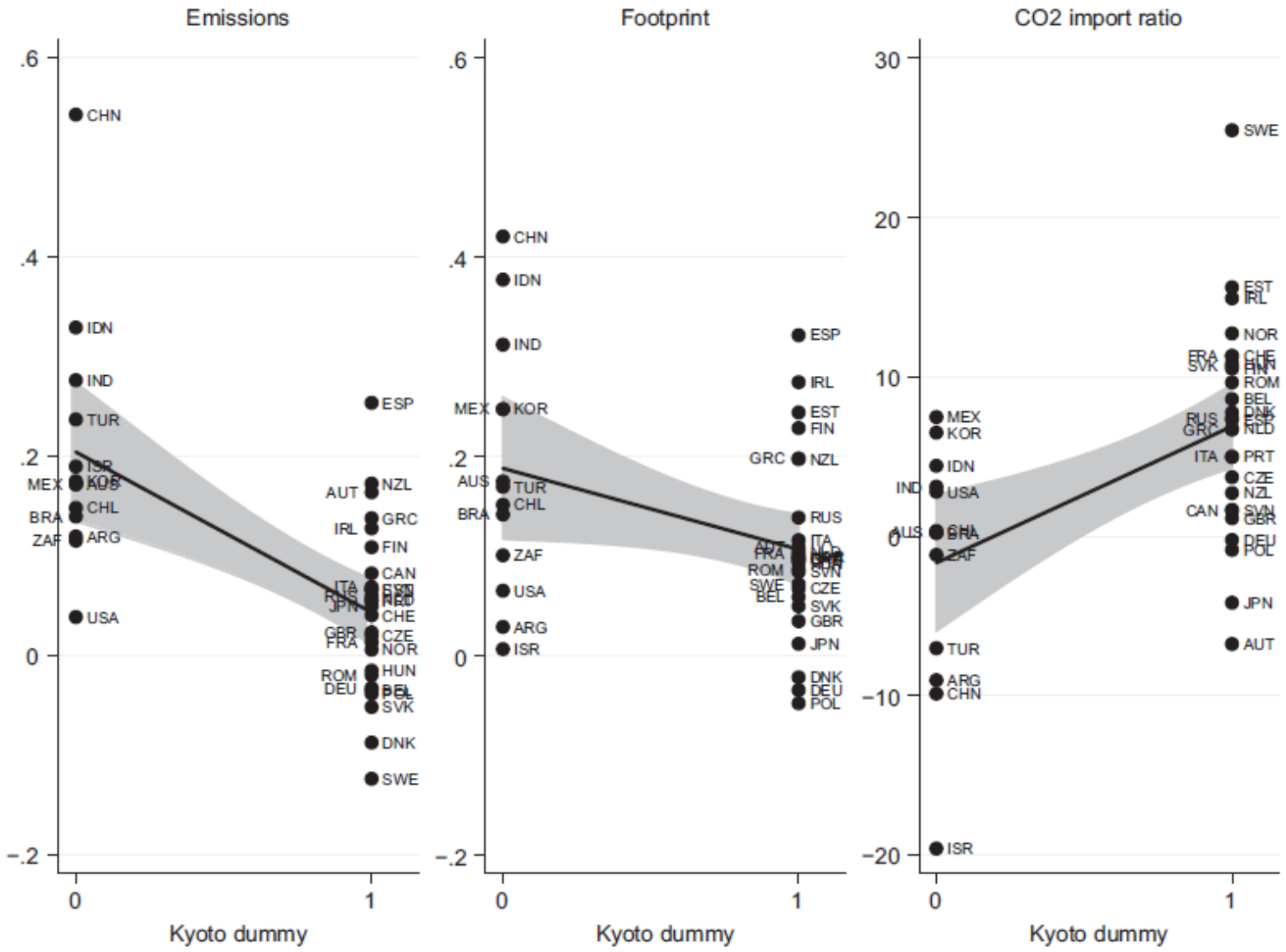
$$\Delta Outcome_{i,t} = \delta + \beta \Delta Kyoto_{i,t} + \xi \Delta \mathbf{X}'_{i,t} + \upsilon_{i,t},$$

$$Outcome_{i,t} \in \left\{ \ln E_{i,t}, \ln F_{i,t}, \frac{EET_{i,t}}{E_{i,t}} \right\},$$

Pre (1995-2000) and post-treatment (2004-2007) periods

¶ **First stage** regressions: as before (IV strategy ICC ratification and its spatial lag)

SIMPLE DIFF-IN-DIFF



REGRESSION ANALYSIS

Dep.var.:	(1) Emissions	(2) Footprint	(7) Emissions	(8) Footprint	(9) Imports	(10) Emissions	(11) Footprint	(12) Imports
Units:	Log *level*		Log *per capita* value		Share[a]	log *per capita* value		Share[a]
Method:	FD-OLS	FD-OLS	FD-IV	FD-IV	FD-IV	FD-IV	FD-IV	FD-IV
Kyoto (0,1)	−0.08*	−0.00	−0.08**	0.03	0.11***	−0.07**	0.06	0.14***
	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.05)	(0.04)
Log pop	1.13***	0.94**						
	(0.36)	(0.43)						
Log GDP	0.38**	0.47***	0.37**	0.49***	0.10	0.13	0.36***	0.21*
	(0.16)	(0.09)	(0.16)	(0.10)	(0.09)	(0.09)	(0.12)	(0.11)
China (0,1)						0.30***	0.18***	−0.10
						(0.08)	(0.05)	(0.07)
Polity (−10 to 10)						0.02*	0.03***	0.01**
						(0.01)	(0.01)	(0.00)
Log stock of other MEAs						0.10	0.05	−0.10
						(0.11)	(0.10)	(0.12)
EU (0,1)						−0.07*	−0.08	−0.01
						(0.04)	(0.05)	(0.05)
Second stage diagnostics								
Adj. R^2	0.54	0.39	0.37	0.31	0.22	0.55	0.45	0.20

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Kyoto did reduce territorial CO_2 emissions, but has not affected countries' CO_2 footprints.

$\Rightarrow$ Non negligible role of trade

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GRAVITY FOR CARBON

The CO_2-content of imports of country m from x in sector s

$$\ln E^s_{mx} = \ln \eta^s_x + \ln Q^s_{mx}$$

- Q^s_{mx} : Quantity index of bilateral trade (***scale effect***). **Inputs**-extended standard gravity.
- $\eta^s_x \equiv \mathbf{e}_x^T \mathbf{A}^s_x$: CO_2-***intensity*** of imports
  - $\mathbf{e}_x$ is the vector of sectoral emission coefficients
  - $\mathbf{A}^s_x$ is the $s-$th column of $(\mathbf{I} - \mathbf{B}_x)^{-1}$, where $\mathbf{B}_x$ is the I/O Matrix of country x
- Climate policy in m and x changes η^s_x and Q^s_{mx}

NEW DATA

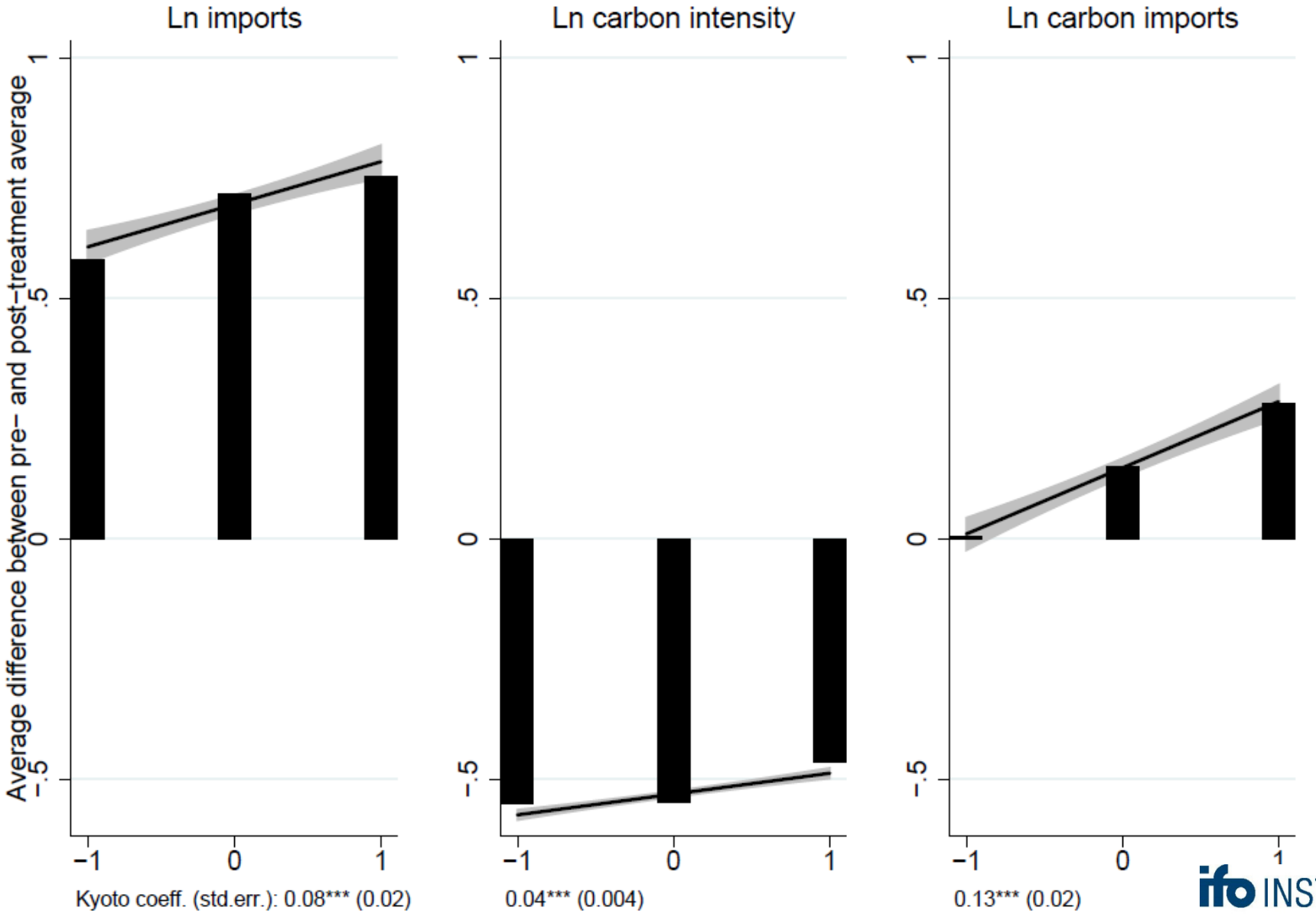
- Using the theoretical model to calculate the empirical ***CO_2-content of bilateral imports***
  - Sectoral trade data (UN Comtrade)
  - Harmonized panel of I/O Tables (OECD)
  - Sectoral output data (OECD STAN)
  - Sectoral CO_2 emissions (IEA)
- Ein ***'three-way'*** panel (country pair $\times$ year $\times$ sector)
  - 40 countries, 80% of global CO_2−emissions
  - 15 sectors (12 tradeable)
  - 11 years (1997-2007)

ECONOMETRIC STRATEGY

"Long fixed-effects"=Diff-in-Diff

- Dummy $KYOTO_{mt} = 1$ if Kyoto Protocol was ***ratified*** in country m at time t ***ratifizert*** and country had committed to a binding emission ceiling
- Identification over **time vaiance** in country-sector-pairs: pre-treatment (1997-2000), post-treatment (2004-2007)
- Differencing eliminates bilateral and country-specific time-invariant components of trade

DIFF-IN-DIFF POOLED DATA



CAUSAL EFFECTS

sector-specific panel estimators

- Three dependent variables: $Y = (E_{mxt}, Q_{mxt}, \eta_{xt})$

$$\begin{aligned} \ln Y_{mxt} &= \beta (KYOTO_{mt} - KYOTO_{xt}) + \gamma POL_{mxt} \\ &+ \nu_x \times \nu_t + \nu_m \times \nu_t + \nu_m \times \nu_x + \varepsilon_{mxt} \end{aligned}$$

- Interactions between year and exporter/importer dummies with the objective to control for
  - ... multilateral trade costs (third country effects),
  - ... the selection of countries into the Protocol and
  - ... country-specific (and global) trends (in a non-parametric manner)
- Identification assumption

$$cov(KYOTO_{mt} - KYOTO_{xt}, \varepsilon_{mxt} | X_{mxt}) = 0$$

BASELINE RESULTS

Dependent Variable	(1) Ln Imports, Q_{mx}	(2) Ln CO_2 Intensity of Imports, η_x	(3) Ln CTT, η_x/η_m	(4) Ln CO_2 Imports, E_{mx}
$DKyoto_{mx}$	0.050***	0.028***	−0.043***	0.078***
	(0.011)	(0.003)	(0.005)	(0.011)
Joint FTA membership	0.103***	0.010		0.113***
	(0.031)	(0.008)		(0.032)
Joint WTO membership	−0.144	−0.001		−0.144
	(0.163)	(0.036)		(0.165)
Joint EU membership	0.019	0.019**		0.038
	(0.035)	(0.009)		(0.035)
Country × Year Effects	Yes	Yes	Yes	Yes
Country pair-sector effects	Yes	Yes	Yes	Yes
Observations	223,499	223,499	215,917	223,499
Number of country pair-sectors	18,588	18,588	18,387	18,588
Adjusted R^2	0.206	0.709	0.036	0.074
F-statistic	46.316	879.091	11.691	15.245
RMSE	0.829	0.179	0.305	0.849

SECTOR-LEVEL RESULTS

Dependent Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Ln Imports		Ln CO_2 Intensity		Ln CO_2 Imports	
Method	FE	Long FE	FE	Long FE	FE	Long FE
(3) Basic metals	0.20***	0.21**	−0.00	0.01	0.20***	0.21**
	(0.04)	(0.08)	(0.01)	(0.01)	(0.04)	(0.08)
(9) Paper, paper products, pulp and printing	0.15***	0.16**	0.02***	0.04***	0.17***	0.19***
	(0.04)	(0.07)	(0.01)	(0.01)	(0.04)	(0.07)
(6) Transport equipment	0.15***	0.18**	0.01	0.01	0.16***	0.21**
	(0.04)	(0.08)	(0.01)	(0.02)	(0.04)	(0.09)
(7) Machinery	0.13***	0.10**	0.01	0.00	0.15***	0.11**
	(0.02)	(0.05)	(0.01)	(0.02)	(0.03)	(0.05)
(5) Other nonmetallic mineral products	0.14***	0.17***	−0.00	0.00	0.14***	0.18**
	(0.03)	(0.07)	(0.01)	(0.02)	(0.03)	(0.07)
(2) Electricity, energy, mining and quarrying	0.08	0.14	0.05***	0.10***	0.13**	0.24**
	(0.06)	(0.12)	(0.01)	(0.02)	(0.06)	(0.12)
(12) Non-specified industries	−0.01	−0.02	0.09***	0.11***	0.09***	0.10**
	(0.02)	(0.04)	(0.01)	(0.02)	(0.03)	(0.05)
(4) Chemicals and petrochemicals	0.02	0.02	0.06***	0.07***	0.08***	0.09*
	(0.03)	(0.05)	(0.01)	(0.02)	(0.03)	(0.06)
(8) Food products, beverages, tobacco	0.01	0.06	0.01**	0.03**	0.02	0.10
	(0.03)	(0.07)	(0.01)	(0.01)	(0.04)	(0.08)
(1) Agriculture, forestry, fishing	−0.04	−0.02	0.02***	0.06***	−0.02	0.05
	(0.04)	(0.08)	(0.01)	(0.01)	(0.04)	(0.08)
(10) Wood and wood products	−0.10**	−0.15	0.02**	0.05***	−0.08*	−0.09
	(0.05)	(0.09)	(0.01)	(0.02)	(0.05)	(0.09)
(11) Textile and leather	−0.12***	−0.19***	0.02***	0.03*	−0.09***	−0.15**
	(0.03)	(0.06)	(0.01)	(0.02)	(0.03)	(0.06)

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Kyoto did increase imports from non-committed countries, the carbon intensity of imports, and the carbon content of imports

IMPLICATIONS FOR POLICY

- **Carbon leakage** is a real possibility and it is quantitatively relevant
- **Need border adjustment tax** (BAT) to stabilize coalition of the willing and to improve effectiveness / efficiency
- Common but differentiated responsibility: **rebate BAT income**
- **New free trade agreements**: link CO2-emission trading systems, harmonize CO2 taxes, allow for BAT

CURRENT ifo RESEARCH

- **Effects of FTAs** on CO2 emissions worldwide
  - Ex post analysis (EU-Korea for the EU Commission)
  - Ex ante analysis, with and without BATs
- **Excessive and inefficient international trade** due to non-internalization of transportation related CO2 emissions: Analysis using an NQTM
- **Role of trade linkages in mitigating damage caused by global warming**