Carbon Tax and Emissions Transfer a Spatial Analysis

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Introduction

Essential facts

- Country tends to import the goods intensive in carbon rather than producing them domestically.
- Goods tend to be imported from near countries.
- Increase of the emissions embodied in exports and imports, around 5% and 10%, respectively.

Carbon emissions affect the neighborhood through two ways:

First

- Pollution at the national level, and transmission to neighboring countries through exports.

Second

- **Transferring the production of their output to tax-exempt third countries.**
- **Imported goods from that country might be exempted from the tax.**

Three important reasons for using input-output model:

First

- Ex-ante analysis can be carried out and serve as an effective tool in quantifying key coefficients changes to CO_2 emissions.

Second

- Dependency and proportionality relations between different sectors (inter-relations between industries).

Third

- Very tractable: the interactions of intermediate sectors and final sectors.

Research questions

Main question

- What is the carbon taxation effect in spatial econometrics approach (direct indirect effects) (Silva Freitas et al., 2016) and (Zhong et al.,2018)?

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Secondary question

- Which sector emitted more pollution through structural decomposition analysis (Perobelli et al., 2015)?

Our contribution

Models

- SDA (structural decomposition analysis), MRIO (multi-regional input-output model), and Spatial econometric models

56 sectors gathered in 5 categories

- Electricity, Manufacturing industries construction, Other sectors, Residential buildings commercial and public services, Transport

43 countries

- 31 OECD countries and 12 other countries

Time period

- 2000-2014

Related literature

CO_2 emission transfers is synthesized into two different strands:

- CO_2 emissions embodied in trade that are generated by goods and services produced in some countries which are consumed in other countries.
- Carbon that is physically in fossil fuels, petroleum-derived products, harvested wood products, crops, and livestock products (Peters et al., 2012).

Ways for equalizing carbon taxes across countries

First

- All countries simply levy the same tax on the carbon content of fossil fuels produced within their borders.

Second

- The production tax base could be modified to include fuel imports taxes to equalize them when production tax is lower in the producing country.

Final

- Destination-based taxation.

Methodology

Explained variables

Emissions embodied in trade

$$LnY_{ijt}^{rs}$$

i: sector i, j= sector j, t: year, r: country r, s: country s
i$\neq j, r \neq s$

- Emissions embodied in export
- Emissions embodied in import

Explanatory variables

LnT_{ijt}^{rs} (Tax variables)

- Before tax (Total emissions before tax)
- After tax (carbon tax, Total emissions after tax, and The tax impact on price index)

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OECD (Dummy Variable)

Main estimating equation

$$LnY_{ijt}^{rs} = \beta_0 + \rho W_{t-1}^{rs} LnY_{ijt}^{rs} + \beta_1 LnX_{ijt}^{rs} + \delta_1 \sum_{ij=1}^{n} W_{ij} LnX_{ijt}^{rs} + U_{ijt}^{rs} + \epsilon_{ijt}^{rs}$$

Measurement and Descriptive Statistics of Variables

Variable	Definition	Unit	Mean	Std.Dev.	Min	Max
EEE	Emissions embodied in exports	Mt	3.4874	1.7788	0.1344	10.5868
EEI	Emissions embodied in imports	Mt	1.8087	1.5514	-1417	6.4543
TAX	carbon tax	Million dollars	8.4638	2.0382	0	11.70127
TEBT	Total emissions before tax	Mt	11.7661	2.7111	4.8204	20.0515
TEAT	Total emissions after tax	mt	8.999	2.8979	1.807	18.0747
IPI	The tax impact on price index	Million dollar	3.6664	3.0262	-5.4033	9.4406
GDP-engi	GDP per unit of energy consumption	Million Dollar/Mt	-11.7465	0.3556	-13.0163	-10.8619
Clean-engi	The ratio of clean energy to total energy use	%	2.3358	1.1753	-2.4383	4.4784
PGDP	Per capita GDP	Million dollars	9.8501	1.0322	6.1983	11.5351
Intermediate-Local	Intermediate inputs in local region	Million dollars	12.5772	1.7475	8.2934	16.8424
Final-Local	Final requirements in local region	Million dollars	12.5545	1.7635	8.4225	16.6653
Intermediate-Other	Intermediate inputs in other regions	Million dollars	9.6786	1.5616	5.3796	13.2202
Final-Other	Final requirements in other regions	Million dollars	9.1475	1.663	4.5644	13.0963
C-emission	Consumer Emissions	Million dollars	17.4695	3.3585	9.188	26.1566
P-emission	Producer Emissions	Million dollars	14.9916	3.1469	6.6068	23.1412
OECD	Belonging to an OECD country	Dummy Variable	0.7209	0.4489	0	1

Results

Results based on two directions

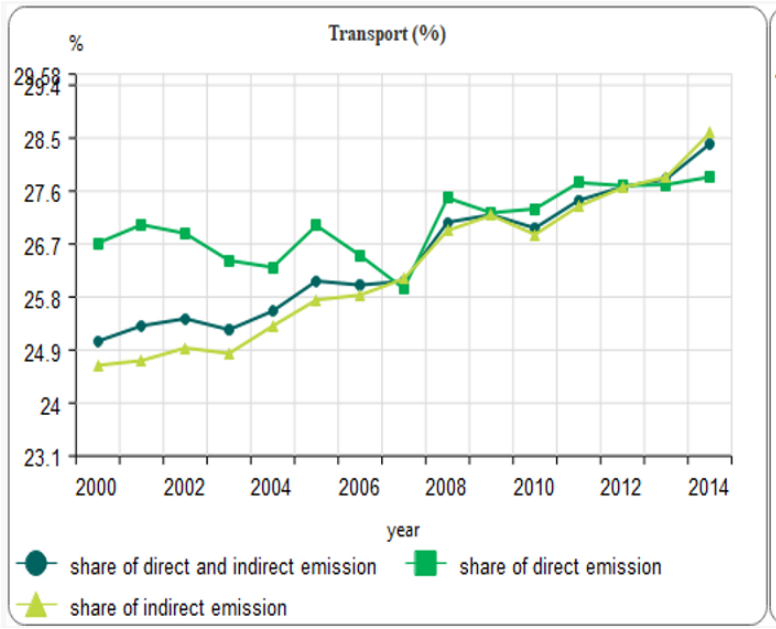
Step I

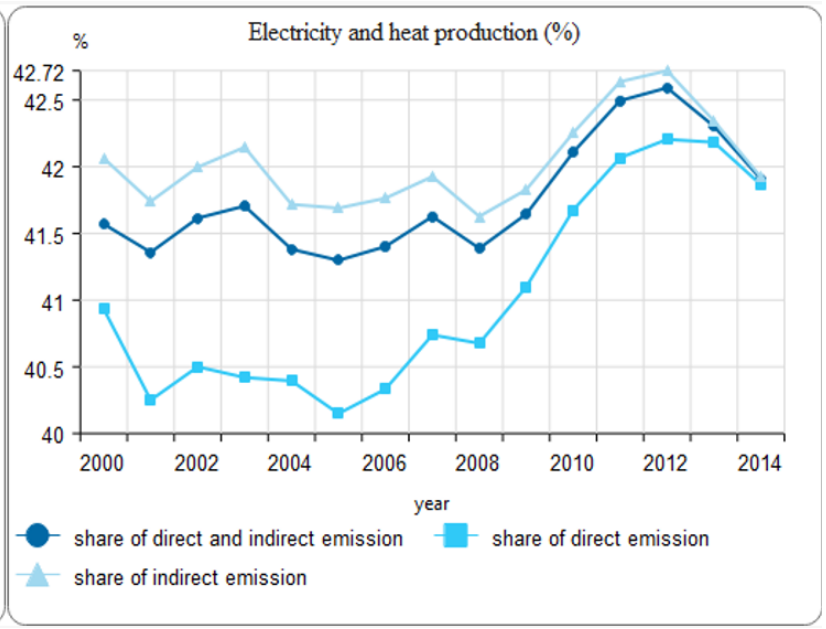
- Recall the secondary question:
  Which sector emitted more pollution?

Step II

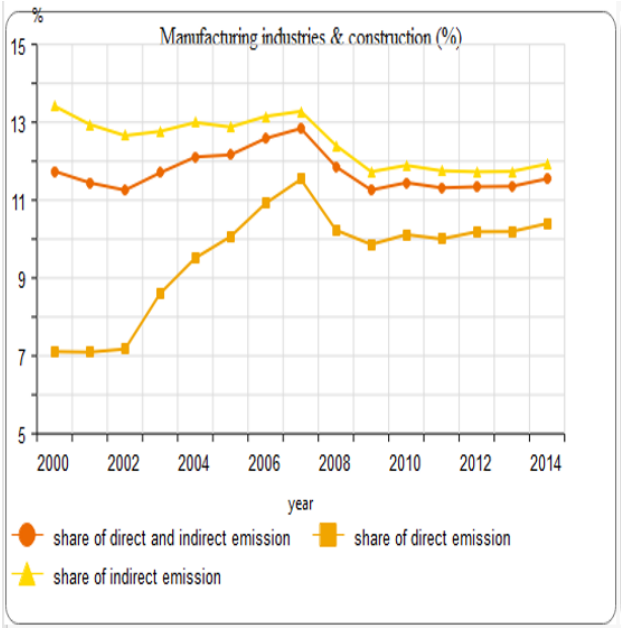
- Recall the main question:
  What is the effect of carbon taxation through carbon embodied emissions in trade?

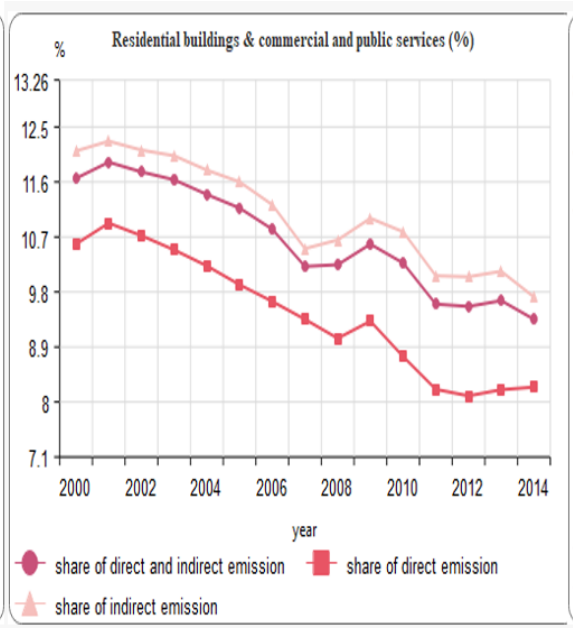
Step I

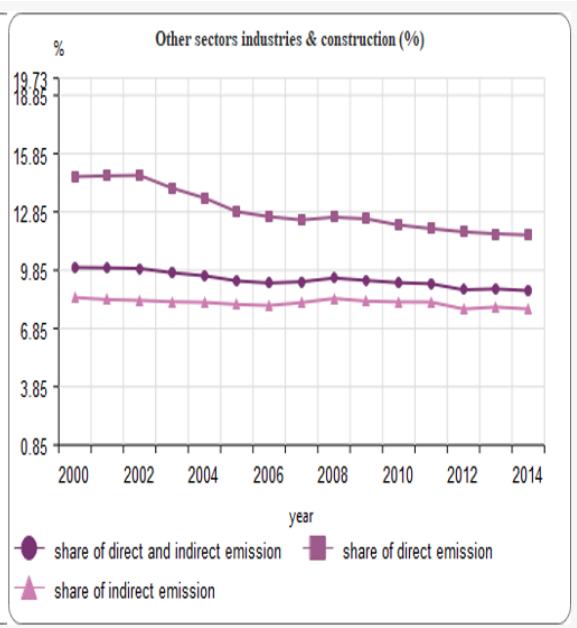

Transport (%)
%
29.58
29.4
28.5
27.6
26.7
25.8
24.9
24
23.1
2000
2002
2004
2006
2008
2010
2012
2014
year
share of direct and indirect emission
share of direct emission
share of indirect emission


Electricity and heat production (%)
%
42.72
42.5
42
41.5
41
40.5
40
2000
2002
2004
2006
2008
2010
2012
2014
year
share of direct and indirect emission
share of direct emission
share of indirect emission

Step I (Cont'd)


Manufacturing industries & construction (%)
%
15
13
11
9
7
5
2000
2002
2004
2006
2008
2010
2012
2014
year
share of direct and indirect emission
share of direct emission
share of indirect emission


Residential buildings & commercial and public services (%)
%
13.26
12.5
11.6
10.7
9.8
8.9
8
7.1
2000
2002
2004
2006
2008
2010
2012
2014
year
share of direct and indirect emission
share of direct emission
share of indirect emission


Other sectors industries & construction (%)
%
19.73
18.85
15.85
12.85
9.85
6.85
3.85
0.85
2000
2002
2004
2006
2008
2010
2012
2014
year
share of direct and indirect emission
share of direct emission
share of indirect emission

Estimation of Panel Spatial Models for Emissions Embodied in Imports Before and After Tax

VARIABLES	$1/d^2$	$EEBT$	$1/d^2$	$EEBT$
	Before Tax		After Tax	
tax	_	_	0.0205	0.0979***
	_	_	(0.0317)	(0.0289)
Inter-L	-5.712***	-2.145*	-2.965***	-0.170
	(1.318)	(1.122)	(1.080)	(0.968)
Final-L	1.416***	0.379*	0.624***	-0.00531
	(0.227)	(0.210)	(0.193)	(0.185)
Inter-O	3.365***	1.204	1.587**	0.0400
	(0.884)	(0.736)	(0.722)	(0.631)
Final-O	1.289***	0.214	0.754*	-0.254
	(0.461)	(0.405)	(0.385)	(0.356)
C-emission	4.918***	1.993*	2.426**	0.0572
	(1.434)	(1.209)	(1.173)	(1.044)
P-emission	-4.958***	-1.802	-2.528**	-0.0196
	(1.429)	(1.200)	(1.171)	(1.037)
ρ	**0.0579*** **	**0.00301*** **	**0.0543*** **	**0.00242*** **
	(0.00457)	(0.000828)	(0.00427)	(0.000774)
δ	1.078***	1.048***	0.843***	0.886***
	(0.0312)	(0.0303)	(0.0244)	(0.0256)

Direct and Indirect Effects of the SDM Model for Emissions Embodied in Imports

Variables	Beta	Total	Direct	InDirect	Beta	Total	Direct	InDirect	Final effect
	Before Tax				After Tax				
tax	_	_	_	_	0.0096	0.0088	0.0019	0.0069	_
teat	_	_	_	_	0.3321	0.3059	0.0663	0.2395	_
tebt	0.0646	0.0596	0.0131	0.0465	_	_	_	_	_
ipi	_	_	_	_	-0.015	-0.0138	-0.003	-0.0108	_
GDP-engi	0.0746	**0.0688**	0.0151	0.0537	-0.0732	**-0.0674**	-0.0146	-0.0528	**-0.1362**
Clean-engi	0.1809	**0.1669**	0.0367	0.1303	0.0797	**0.0734**	0.0159	0.0575	**-0.0935**
pgdp	-0.0295	**-0.0272**	-0.006	-0.0213	-0.0747	**-0.0688**	-0.0149	-0.0539	**-0.0416**
Intermediate-Local	2.4115	**2.2248**	0.4887	1.736	2.6563	**2.4468**	0.5307	1.9161	**0.222**
Final-Local	0.7851	**0.7243**	0.1591	0.5652	0.1529	**0.1408**	0.0305	0.1103	**-0.5835**
Intermediate-Other	-1.0872	**-1.003**	-0.2203	-0.7826	-1.3974	**-1.2872**	-0.2792	-1.008	**-0.2842**
Final-Other	-1.5743	**-1.4524**	-0.3191	-1.1333	-1.2321	**-1.135**	-0.2462	-0.8888	**0.3174**
C-emission	-3.1963	**-2.9488**	-0.6478	-2.301	-3.141	**-2.8933**	-0.6276	-2.2658	**0.0555**
P-emission	3.198	**2.9504**	0.6481	2.3022	3.0964	**2.8522**	0.6186	2.2335	**-0.0982**
oecd	0.621	**0.5729**	0.1259	0.4471	0.5247	**0.4833**	0.1048	0.3785	**-0.0896**

All coefficients are significant.

Conclusions

Main results

- The spatial spillovers positive, significant and accepted sign.
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Secondary results

- Electricity and heat production is the most polluting sector.
- Residential buildings, commercial and public services is the less polluting sector.

Conclusions

First

- Tax implementation have been effective in emission embodied in import with considering trade matrix, but this effect is less tangible when considering the geographical distance situation.

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Second

- Tax implementation have been effective in emission embodied in export with the weight matrix of geographical distance, but this effect is less tangible when trade is considered as the weight matrix.

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First

- Tax implementation have been effective in emission embodied in import with considering trade matrix, but this effect is less tangible when considering the geographical distance situation.

Second

- Tax implementation have been effective in emission embodied in export with the weight matrix of geographical distance, but this effect is less tangible when trade is considered as the weight matrix.

Third

- The government can develop more rules when setting up the tax rate.

Policy recommendations

First

- EU zone or other integrated zones should harmonize this kind of increase in emissions.

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- There is the spillover effect before and after taxation. So, the government should care about their decisions on environmental taxation in their country and their neighbors.

Third

- Integrated regions are good to avoid the carbon tax spillover effect.

Thanks for your attention!

Are there questions?

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Appendix

$$\beta_{\mathbf{2}}\mathbf{LnX}^{\mathbf{rs}}_{\mathbf{it}} = \begin{cases} \beta_4 LnGDP.engi^{rs}_{it} + \beta_5 LnClean.engi^{rs}_{it} + \beta_6 LnPGDP^{rs}_{it} + \\ \delta_4 \sum_{ij=1}^{n} W_{ij} LnGDP.engi^{rs}_{it} + \delta_5 \sum_{ij=1}^{n} W_{ij} LnClean.engi^{rs}_{it} + \\ \delta_6 \sum_{ij=1}^{n} W_{ij} LnPGDP^{rs}_{it} \end{cases}$$

$$\beta_{\mathbf{3}}\mathbf{LnZ}^{\mathbf{rs}}_{\mathbf{ijt}} = \begin{cases} \beta_7 LnInter.L^{rs}_{ijt} + \beta_8 LnFinal.L^{rs}_{ijt} + \beta_9 LnInter.O^{rs}_{ijt} + \\ \beta_{10} LnFinal.O^{rs}_{ijt} + \beta_{11} LnC.emission^{rs}_{ijt} + \beta_{12} LnP.emission^{rs}_{ijt} \\ + \delta_7 \sum_{ij=1}^{n} W_{ij} LnInter.L^{rs}_{ijt} + \delta_8 \sum_{ij=1}^{n} W_{ij} LnFinal.L^{rs}_{ijt} + \\ \delta_9 \sum_{ij=1}^{n} W_{ij} LnInter.O^{rs}_{ijt} + \delta_{10} \sum_{ij=1}^{n} W_{ij} LnFinal.O^{rs}_{ijt} + \\ \delta_{11} \sum_{ij=1}^{n} W_{ij} LnC.emission^{rs}_{ijt} + \delta_{12} \sum_{ij=1}^{n} W_{ij} LnP.emission^{rs}_{ijt} \end{cases}$$

$$\beta_{\mathbf{1}}\mathbf{LnT}_{\mathbf{it}} = \begin{cases} \beta_1 LnTEBT^{rs}_{ijt} + \delta_1 \sum_{ij=1}^{n} W_{ij} LnTEBT^{rs}_{ijt} \\ \beta_1 LnTAX^{rs}_{t} + \beta_2 LnTEAT^{rs}_{ijt} + \beta_3 LnIPI^{rs}_{ijt} + \\ \delta_1 \sum_{ij=1}^{n} W_{ij} LnTAX^{rs}_{t} + \delta_2 \sum_{ij=1}^{n} W_{ij} LnTEAT^{rs}_{ijt} + \\ \delta_3 \sum_{ij=1}^{n} W_{ij} LnIPI^{rs}_{ijt} \end{cases}$$

Results of Selection Model Tests for Emissions Embodied in Exports Before and After Tax

			SDM	SAC	SEM	SAR
After Tax	Log Likelihood Function	$1/d^2$	**-455.908**	-501.745	-501.071	-695.792
		$EEBT$	**-746.597**	-766.162	-774.967	-793.501
Before Tax	Log Likelihood Function	$1/d^2$	**-514.411**	-547.417	-553.264	-780.331
		$EEBT$	**-815.793**	-835.839	-877.358	-869.983
After Tax	LR Test	$1/d^2$	858.6497 ***	399.7964 ***	**1296.0179*** **	251.9009***
		$EEBT$	36.9630***	53.1820***	**72.6409*** **	16.3346***
Before Tax	LR Test	$1/d^2$	1069.4587 ***	11.9344 ***	**1376.8246*** **	237.8938***
		$EEBT$	**34.6413*** **	0.0019 ***	6.7194 ***	22.2970***
After Tax	LM Error (Burridge)	$1/d^2$	1835.3325***	2285.3894 ***	2285.3894***	2285.3894***
		$EEBT$	55.0979***	429.4411 ***	429.4411***	429.4411***
Before Tax	LM Error (Burridge)	$1/d^2$	2080.2515 ***	2600.1593 ***	2600.1593***	2600.1593***
		$EEBT$	55.1978 ***	505.2714***	505.2714***	505.2714***
After Tax	LM Error (Robust)	$1/d^2$	85.8318 ***	682.2846***	682.2846***	682.2846***
		$EEBT$	13.3914***	156.6260 ***	156.6260 ***	156.6260***
Before Tax	LM Error (Robust)	$1/d^2$	4.97e+04 ***	1.50e+05 *	1.50e+05*	1.50e+05*
		$EEBT$	231.4984***	2.36e+04**	2.36e+04 **	2.36e+04**
After Tax	LM Lag (Anselin)	$1/d^2$	1764.9363 ***	3728.4581***	3728.4581***	3728.4581***
		$EEBT$	43.5225***	304.3896 ***	304.3896***	304.3896***
Before Tax	LM Lag (Anselin)	$1/d^2$	2225.5606 ***	3444.2500***	3444.2500 ***	3444.2500***
		$EEBT$	46.6183 ***	379.6509***	379.6509 ***	379.6509***
After Tax	LM Lag (Robust)	$1/d^2$	15.4356 ***	2125.3533 ***	2125.3533 ***	2125.3533***
		$EEBT$	1.8159 *	31.5745 ***	31.5745 ***	31.5745***
Before Tax	LM Lag (Robust)	$1/d^2$	4.98e+04 ***	1.51e+05 *	1.51e+05*	1.51e+05*
		$EEBT$	222.9190***	2.34e+04 **	2.34e+04**	2.34e+04**
After Tax	AIC[1]	$1/d^2$	969.8165	1033.489	1034.143	1423.584
		$EEBT$	1551.194	1566.325	1581.934	1619.001
Before Tax	AIC	$1/d^2$	1078.823	1124.834	1134.528	1588.663
		$EEBT$	1681.586	1701.678	1780.716	1767.966
After Tax	BIC [2]	$1/d^2$	1099.425	1100.528	1105.651	1495.092
		$EEBT$	1680.802	1642.302	1653.442	1690.509
Before Tax	BIC	$1/d^2$	1190.554	1191.873	1197.098	1651.232
		$EEBT$	1793.318	1768.717	1838.817	1830.536

Results of Selection Model Tests for Emissions Embodied in Imports Before and After Tax

			SDM	SAC	SEM	SAR
After Tax	Log Likelihood	$1/d^2$	**-753.616**	-792.134	-793.743	-855.965
		$EEBT$	**-777.319**	-857.121	-859.943	-870.987
Before Tax	Log Likelihood	$1/d^2$	**-902.163**	-965.4405	-967.678	-1003.35
		$EEBT$	**-878.168**	-1031.13	-986.481	-1026.89
After Tax	LR Test	$1/d^2$	162.1024***	2.7493**	**210.8688*** **	45.1557***
		$EEBT$	9.7860***	6.5061***	**31.6680*** **	13.3546***
Before Tax	LR Test	$1/d^2$	159.9940***	4.4183***	**187.0732*** **	77.6447***
		$EEBT$	13.2280***	4.2578***	**118.0840*** **	25.1705***
After Tax	LM Error (Burridge)	$1/d^2$	430.8375***	620.2473***	620.2473***	620.2473***
		$EEBT$	6.4993***	106.5023***	106.5023***	106.5023***
Before Tax	LM Error (Burridge)	$1/d^2$	317.4636***	352.4611***	352.4611***	352.4611***
		$EEBT$	6.8341***	176.4571***	176.4571***	176.4571***
After Tax	LM Error (Robust)	$1/d^2$	321.6487***	921.3551***	921.3551***	921.3551***
		$EEBT$	2.8341**	0.7122	0.7122	0.7122
Before Tax	LM Error (Robust)	$1/d^2$	38.5859***	36.3757***	36.3757***	36.3757***
		$EEBT$	4.3674***	9.4530***	9.4530***	9.4530***
After Tax	LM Lag (Anselin)	$1/d^2$	470.2623***	406.8592***	406.8592***	406.8592***
		$EEBT$	4.0149***	111.1076***	111.1076***	111.1076***
Before Tax	LM Lag (Anselin)	$1/d^2$	331.8253***	376.5123***	376.5123***	376.5123***
		$EEBT$	4.6548***	195.7482***	195.7482***	195.7482***
After Tax	LM Lag (Robust)	$1/d^2$	361.0735***	707.9670***	707.9670***	707.9670***
		$EEBT$	0.3497	5.3175***	5.3175***	5.3175***
Before Tax	LM Lag (Robust)	$1/d^2$	52.9475***	60.4269***	60.4269***	60.4269***
		$EEBT$	2.1881**	28.7441***	28.7441***	28.7441***
After Tax	AIC[3]	$1/d^2$	1565.232	1618.268	1619.485	1743.929
		$EEBT$	1612.637	1748.241	1751.886	1773.974
Before Tax	AIC	$1/d^2$	1854.327	1960.881	1963.355	2034.695

Estimation of Panel Spatial Models for Emissions Embodied in Exports Before and After Tax

VARIABLES	$1/d^2$	$EEBT$	$1/d^2$	$EEBT$
	Before Tax		After Tax	
tax	_	_	0.0418**	0.0542**
	_	_	(0.0176)	(0.0246)
Inter-L	-1.498**	-1.036	-0.275	-0.0965
	(0.602)	(0.875)	(0.576)	(0.798)
Final-L	0.802***	0.764***	0.598***	0.619***
	(0.106)	(0.164)	(0.101)	(0.151)
Inter-O	0.731*	0.228	-0.0979	-0.404
	(0.404)	(0.575)	(0.388)	(0.523)
Final-O	0.620***	0.283	0.285	0.103
	(0.209)	(0.312)	(0.203)	(0.288)
C-emission	1.792***	1.181	0.565	0.190
	(0.654)	(0.942)	(0.625)	(0.858)
P-emission	-1.688***	-0.906	-0.477	-0.0221
	(0.652)	(0.935)	(0.625)	(0.852)
ρ	**0.0823*** **	**0.00307*** **	**0.0798*** **	**0.00318*** **
	(0.00252)	(0.000521)	(0.00272)	(0.000523)
δ	0.523***	0.857***	0.479***	0.770***
	(0.0146)	(0.0239)	(0.0134)	(0.0214)

Direct and Indirect Effects of the SDM Model for Emissions Embodied in exports

Variables	Beta	Total	Direct	InDirect	Beta	Total	Direct	InDirect	Final effect
	Before Tax				After Tax				
tax	_	_	_	_	0.0017	0.0012	0.0001	0.0011	_
teat	_	_	_	_	0.0492	0.0359	0.0029	0.033	_
tebt	0.0053	0.004	0.0003	0.0036	_	_	_	_	_
ipi	_	_	_	_	-0.0017	-0.0013	-0.0001	-0.0012	_
GDP-engi	0.0423	**0.0318**	0.0028	0.029	0.013	**0.0095**	0.0008	0.0087	**-0.0223**
Clean-engi	-0.0151	**-0.0113**	-0.001	-0.0104	-0.028	**-0.0205**	-0.0016	-0.0188	**-0.0092**
pgdp	0.0293	**0.0221**	0.0019	0.0201	0.0174	**0.0127**	0.001	0.0116	**-0.0094**
Intermediate-Local	-0.0899	**-0.0677**	-0.0059	-0.0618	0.0848	**0.0618**	0.005	0.0568	**0.1295**
Final-Local	0.9331	**0.7025**	0.0613	0.6412	0.8341	**0.6084**	0.049	0.5594	**-0.0941**
Intermediate-Other	0.0378	**0.0285**	0.0025	0.026	-0.082	**-0.0598**	-0.0048	-0.055	**-0.0883**
Final-Other	0.0695	**0.0523**	0.0046	0.0477	0.0795	**0.058**	0.0047	0.0533	**0.0057**
C-emission	0.0874	**0.0658**	0.0057	0.0601	-0.0323	**-0.0236**	-0.0019	-0.0217	**-0.0894**
P-emission	-0.0978	**-0.0736**	-0.0064	-0.0672	0.0066	**0.0048**	0.0004	0.0045	**0.0784**
oecd	-0.0869	**-0.0655**	-0.0057	-0.0597	-0.0928	**-0.0677**	-0.0055	-0.0622	**-0.0022**

All coefficients are significant.