Emissions Trends and Labour Productivity Dynamics

Sector Heterogeneous Analyses of Decoupling/Recoupling on a 1990-2007 Italian NAMEA

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Motivation and objective

- Vast **empirical** literature on **delinking/EKC** (Environmental Kuznets Curve) trends for air emissions $\Rightarrow$ **mixed** results
- **Lack** of robust **sector**-level analyses

Our contribution:

- From cross-country to **sector-level** analyses of the relationship between **economic performance** and **environmental efficiency**
- **Italy leader** in the supply of high quality **environmental accounts (NAMEA)**, with a very long time series of sector data (1990-2007)

Main findings

- High degree of **heterogeneity** among **sectors**, **macro-sectors** and type of **emissions**
- **Better** performance for **pollutants** than for CO_2
- **Weak** relevance of sector **innovation** (in terms of general R&D expenditure) on environmental efficiency
- Multiple role of **trade** $\Rightarrow$ race-to-the-**top** (EU15 trade) + race-to-the-**bottom** (extra EU15 trade)

Theoretical background

- **EKC** (Environmental Kuznets Curve)
  - See **survey** by Dinda (2005 - Ecological Economics)
  - From cross-country to **sector** approach
- **Eco-innovation**
  - **Porter** Hypothesis (Porter and van der Linde, 1995) or **trade-off** (Jaffe et al., 1995)
  - Recent **sector analysis** to test the Porter Hypothesis (e.g. Cole et al. 2005)
- **Trade and the environment**
  - Efficient **specialization** (i.e. comparative advantage + factor endowment)
  - **Pollution Haven** Effect
  - "Trade and the Environment", Copeland and Taylor (2003)

Environmental Kuznets Curve

Eco-innovation

- **Porter Hypothesis** ⇒ **complementarity** between environmental efficiency and economic productivity ⇒ double positive effect of well designed environmental policy
- **Traditional** idea ⇒ **diversion** of economic resources to meet environmental goals ⇒ **trade-off**
- The role of **R&D** ⇒ "The **two faces** of innovation" (Cohen and Levinthal, 1989)
  - **Direct** effect ⇒ anecdotal evidence of **small** fraction of **'green'** R&D on total R&D (e.g. Antonioli and Mazzanti (2009) with firm-level data for Emilia Romagna)
  - R&D directed to **adopt** innovations
- **Italy** ⇒ **no-policy** scenario in greenhouse gases

Trade and environmental efficiency

- **Pollution Haven Effect** $\Rightarrow$ displacement of **dirty** industries towards countries with **less stringent** environmental **regulations** (low-income countries) $\Rightarrow$ race-to-the-**bottom**
- **Factor endowment** + comparative **advantage** $\Rightarrow$ **high-income** countries specialize in **capital** (pollution) intensive industries
- **Knowledge spillovers** $\Rightarrow$ **diffusion** of environmental innovation through trade $\Rightarrow$ race-to-the-**top**?

Data sources

- **Emissions** ⇒ Italian **NAMEA** (National Accounting Matrix including Environmental Accounts) by **Istat**
  - CO_2, SOx, NOx
  - 29 branches (Nace Rev. 1.1)
  - 1990-2007
- **Value added** and **labour** ⇒ National accounts (supply and use tables) by Istat
- Sector **trade** ⇒ National accounts (supply and use tables) and COEWEB database by Istat ⇒ 1995-2005
- **Research and development** expenditure ⇒ ANBERD Database (OECD) ⇒ 1991-2004

Econometric models I

- **Environmental Kuznets Curve** (EKC)

$$\begin{aligned}\log(E_{st}/L_{st}) &= \beta_{0s} + \beta_1 \log(VA_{st}/L_{st}) + \beta_2[\log(VA_{st}/L_{st})]^2 + \\ &+ \beta_3 Stag_{0,1} + \varepsilon_{st}\end{aligned}$$

- **STIRPAT**

$$\begin{aligned}\log(E_{st}) &= \delta_{0s} + \delta_1 \log(VA_{st}/L_{st}) + \delta_2[\log(VA_{st}/L_{st})]^2 + \\ &+ \delta_3 \log(L_{st}) + \delta_4[\log(L_{st})]^2 + \delta_5 Stag_{0,1} + \epsilon_{st}\end{aligned}$$

Stagnation of labour productivity from **2001** $\Rightarrow$ possible effects of the ratification of **Kyoto protocol**?

Aggregate trends (1990=100)

Econometric models II

- EKC and STIRPAT (**fixed effects**) $\Rightarrow$ **aggregate**, **manufacturing** and **services**
- **Extensions**:
  - **Trade openness** (TO) $\Rightarrow \frac{Imp_{st}+Exp_{st}}{VA_{st}} \Rightarrow$ **EU15** vs **extra-EU15** $\Rightarrow$ manufacturing
  - **Research and development** $\Rightarrow \log(R\&D_{st}/VA_{st}) \Rightarrow$ manufacturing
- EKC with **SUR** (Seemingly Unrelated Regressions) $\Rightarrow$ **heterogeneous** and **homogeneous** estimates for manufacturing

Emission trends (aggregate; 1990=100)

EKC models for CO_2

	EKC 1 [aggr]	EKC 2 [manuf]	EKC 3 [serv]	EKC 4a [TO_{EU15}]	EKC 4b [$TO_{extraEU15}$]	EKC 5 [R&D/VA]
	$\ln(CO_2/L)$	$\ln(CO_2/L)$	$\ln(CO_2/L)$	$\ln(CO_2/L)$	$\ln(CO_2/L)$	$\ln(CO_2/L)$
ln(VA/L)	0.422***	2.917***	-7.133***	1.750***	1.817***	2.954***
	[0.06]	[0.41]	[1.38]	[0.57]	[0.60]	[0.45]
$(\ln(VA/L))^2$		-0.292***	0.879***	-0.168***	-0.179***	-0.297***
		[0.04]	[0.18]	[0.06]	[0.06]	[0.05]
Stagnation	0.030**	0.006	-0.041**	0.021	0.024	0.006
	[0.01]	[0.02]	[0.02]	[0.01]	[0.02]	[0.02]
	(103.01%)	(100.61%)	(96.00%)	(102.15%)	(102.40%)	(100.62%)
TO_{EU15}				-0.117**		
				[0.05]		
$TO_{extraEU15}$					-0.078*	
					[0.04]	
ln(R&D/VA)						0.042***
						[0.02]
R^2 (within)	0.167	0.246	0.224	0.081	0.064	0.316
F test	34.53	20.25	17.39	3.92	3.18	23.32
N*T	522	252	162	154	154	196
Period	1990-2007	1990-2007	1990-2007	1995-2005	1995-2005	1991-2004
Turning point		147.397***	57.719***	181.820***	157.905***	143.611***
		[13.42]	[4.68]	[33.77]	[34.77]	[24.59]
Shape (VA/L)	Linear	Inverted U shape	U shape	Inverted U shape	Inverted U shape	Inverted U shape

Sector heterogeneity: CO_2 in services

EKC models for NOx

	EKC 1 [aggr]	EKC 2 [manuf]	EKC 3 [serv]	EKC 4a [TO_{EU15}]	EKC 4b [$TO_{extraEU15}$]	EKC 5 [R&D/VA]
	ln(NOx/L)	ln(NOx/L)	ln(NOx/L)	ln(NOx/L)	ln(NOx/L)	ln(NOx/L)
ln(VA/L)	-0.116	-4.036***	-9.428***	0.182	0.030	-4.725***
	[0.09]	[0.59]	[1.73]	[0.13]	[0.17]	[0.72]
$(\ln(VA/L))^2$		0.426***	1.145***			0.453***
		[0.06]	[0.23]			[0.08]
Stagnation	-0.250***	-0.195***	-0.248***	-0.154***	-0.133***	-0.225***
	[0.02]	[0.02]	[0.03]	[0.02]	[0.02]	[0.03]
	(77.86%)	(82.24%)	(78.02%)	(85.71%)	(87.57%)	(79.88%)
TO_{EU15}				-0.233		
				[0.15]		
$TO_{extraEU15}$					-0.241**	
					[0.10]	
ln(R&D/VA)						0.081***
						[0.03]
R^2 (within)	0.255	0.383	0.344	0.356	0.372	0.392
F test	100.66	64.68	36.02	35.76	41.64	29.39
N*T	522	252	162	154	154	196
Period	1990-2007	1990-2007	1990-2007	1995-2005	1995-2005	1991-2004
Turning point		113.976***	61.361***			183.648***
		[16.49]	[5.58]			[58.44]
Shape (VA/L)	No significant relation	U shape	U shape	No significant relation	No significant relation	U shape

Sector heterogeneity: NOx in manufacturing

EKC models for SOx

	EKC 1 [aggr]	EKC 2 [manuf]	EKC 3 [serv]	EKC 4a [TO_{EU15}]	EKC 4b [$TO_{extraEU15}$]	EKC 5 [R&D/VA]
	ln(SOx/L)	ln(SOx/L)	ln(SOx/L)	ln(SOx/L)	ln(SOx/L)	ln(SOx/L)
ln(VA/L)	-6.752***	-13.750***	-31.646***	-11.312***	-10.124***	-13.767***
	[1.48]	[1.48]	[7.78]	[3.12]	[3.84]	[1.66]
$(\ln(VA/L))^2$	0.633***	1.363***	3.818***	1.090***	0.921**	1.332***
	[0.17]	[0.16]	[1.01]	[0.32]	[0.42]	[0.18]
Stagnation	-1.256***	-0.941***	-1.162***	-0.631***	-0.592***	-0.715***
	[0.07]	[0.07]	[0.11]	[0.07]	[0.07]	[0.07]
	(28.47%)	(39.04%)	(31.30%)	(53.19%)	(55.30%)	(48.90%)
TO_{EU15}				-0.971***		
				[0.25]		
$TO_{extraEU15}$					-0.758**	
					[0.37]	
ln(R&D/VA)						0.009
						[0.05]
R^2 (within)	0.550	0.684	0.927	0.540	0.526	0.580
F test	222.3	163.87	45.93	42.49	40.88	66.9
N*T	522	252	162	154	154	196
Period	1990-2007	1990-2007	1990-2007	1995-2005	1995-2005	1991-2004
Turning point	206.955***	154.812***	63.070***	179.346***	243.862**	175.743***
	[66.86]	[11.99]	[7.35]	[25.24]	[116.25]	[23.45]
Shape (VA/L)	U shape	U shape	U shape	U shape	U shape	U shape

SUR constrained estimates (manufacturing)

	SUR	SUR	SUR
	[manuf]	[manuf]	[manuf]
	ln(CO2/L)	ln(NOx/L)	ln(SOx/L)
ln(VA/L)	2.743***	-3.836***	-11.904***
	[0.09]	[0.14]	[0.48]
$(\ln(VA/L))^2$	-0.275	0.409***	1.185***
	[0.01]	[0.02]	
Stagnation	-0.010**	-0.190***	-0.887***
	[0.01]	[0.01]	[0.05]
	(101.06%)	(82.67%)	(41.17%)
Breusch-Pagan test of independence (Chi2)	488.022***	412.214***	652.702***
Test of aggregation bias (Chi2)	5390.40***	12024.73***	4069.00***
N*T	252	252	252
Period	1990-2007	1990-2007	1990-2007
Turning point	147.017***	108.177***	151.558***
	[3.29]	[3.46]	[2.80]
Shape (VA/L)	Inverted U shape	U shape	U shape

Manufacturing emissions (CO_2)

SUR unconstrained estimates for CO_2/L

Branch	ln(VA/L)	$(\ln(VA/L))^2$	TP	VA/L		Stagn.	Stagn. (%)
				Min	Max		
DA	1.932***			37.986	47.948	0.228***	125.62%
	[0.19]					[0.04]	
DB	19.530***	-2.784***	33.349***	23.336	34.776	-0.078**	92.53%
	[2.24]	[0.33]	[0.53]			[0.04]	
DC	42.650***	-6.179***	31.532***	25.111	33.814	0.008	100.78%
	[2.90]	[0.42]	[0.15]			[0.03]	
DD	21.248***	-3.091***	31.079***	22.939	32.989	-0.021	97.90%
	[2.50]	[0.37]	[0.42]			[0.03]	
DE	-24.085*	3.407**	34.281***	40.946	51.457	0.105***	111.13%
	[13.23]	[1.73]	[5.06]			[0.03]	
DF	0.090***			89.077	261.850	0.077**	108.04%
	[0.03]					[0.03]	
DG	27.152***	-3.261***	64.280***	56.996	82.713	-0.101***	90.42%
	[7.65]	[0.90]	[1.52]			[0.03]	
DH	50.895***	-6.648***	45.968***	40.125	50.595	0.028	102.87%
	[5.17]	[0.68]	[0.27]			[0.02]	
DI	-31.659***	4.357***	37.844***	37.130	50.540	-0.005	99.52%
	[4.11]	[0.55]	[0.69]			[0.02]	
DJ	45.074***	-6.281***	36.173***	32.654	44.282	-0.149***	86.14%
	[8.81]	[1.21]	[0.52]			[0.04]	
DK	108.595***	-13.918***	49.458***	42.191	52.285	-0.026	97.45%
	[16.04]	[2.08]	[0.48]			[0.05]	
DL	34.711***	-4.335***	54.786***	37.376	49.207	-0.012	98.75%
	[4.37]	[0.57]	[1.52]			[0.03]	
DM	-61.657***	8.170***	43.516***	38.021	47.109	0.052	105.35%
	[20.13]	[2.68]	[0.60]			[0.04]	
DN	56.448***	-7.937***	35.024***	28.908	36.109	0.049**	104.98%
	[4.60]	[0.66]	[0.24]			[0.02]	

Manufacturing emissions (NOx)

SUR unconstrained estimates for NOx/L

Branch	ln(VA/L)	$(\ln(VA/L))^2$	TP	VA/L		Stagn.	Stagn. (%)
				Min	Max		
DA	-57.670***	7.507***	46.563***	37.986	47.948	0.038	103.85%
	[8.95]	[1.19]	[0.65]			[0.06]	
DB	-12.547***	1.638***	46.032***	23.336	34.776	-0.156***	85.53%
	[3.86]	[0.57]	[7.36]			[0.05]	
DC	-0.656***			25.111	33.814	-0.410***	66.37%
	[0.11]					[0.06]	
DD	21.385***	-3.300***	25.537***	22.939	32.989	-0.224***	79.95%
	[5.32]	[0.80]	[0.69]			[0.03]	
DE	89.272***	-11.401***	50.148***	40.946	51.457	-0.019	98.12%
	[23.61]	[3.08]	[1.27]			[0.04]	
DF	0.577***			89.077	261.850	-0.087	91.69%
	[0.06]					[0.06]	
DG	138.738***	-16.918***	60.359***	56.996	82.713	0.104	110.92%
	[17.76]	[2.09]	[1.14]			[0.09]	
DH	-59.865***	7.614***	50.978***	40.125	50.595	-0.236***	78.95%
	[14.59]	[1.92]	[1.88]			[0.07]	
DI	-14.013***	1.893***	40.531***	37.130	50.540	-0.065***	93.66%
	[5.02]	[0.67]	[1.11]			[0.02]	
DJ	55.087***	-7.739***	35.133***	32.654	44.282	-0.208***	81.21%
	[11.34]	[1.55]	[0.84]			[0.07]	
DK	85.372***	-11.089***	46.964***	42.191	52.285	-0.264***	76.80%
	[11.79]	[1.53]	[0.29]			[0.03]	
DL	43.420***	-5.715***	44.639***	37.376	49.207	-0.268***	76.50%
	[5.18]	[0.68]	[0.24]			[0.02]	
DM	-15.893***	1.864***	71.108***	38.021	47.109	-0.057**	94.46%
	[5.33]	[0.71]	[13.20]			[0.03]	
DN	31.778***	-4.630***	30.935***	28.908	36.109	-0.291***	74.71%
	[6.49]	[0.93]	[0.50]			[0.02]	

Manufacturing emissions (SOx)

SUR unconstrained estimates for SOx/L

Branch	ln(VA/L)	$(\ln(VA/L))^2$	TP	VA/L		Stagn.	Stagn. (%)
				Min	Max		
DA	-57.461*	7.133*	56.146***	37.986	47.948	-0.780***	45.85%
	[29.52]	3.920886	[8.31]			[0.14]	
DB	64.299***	-9.945***	25.350***	23.336	34.776	-1.164***	31.23%
	[11.11]	[1.66]	[0.60]			[0.14]	
DC	29.847***	-4.848***	21.723***	25.111	33.814	-1.240***	28.93%
	[11.29]	[1.66]	[2.46]			[0.20]	
DD	53.465***	-8.903***	20.138***	22.939	32.989	-0.983***	37.41%
	[13.16]	[1.97]	[1.52]			[0.12]	
DE	209.793***	-28.216***	41.168***	40.946	51.457	-0.827***	43.75%
	[47.33]	[6.19]	[1.01]			[0.12]	
DF	5.008*	-0.437*	309.531**	89.077	261.850	-0.412***	66.21%
	[2.58]	0.2557	[128.84]			[0.11]	
DG	158.338***	-19.210***	61.639***	56.996	82.713	-0.718***	48.77%
	[31.06]	[3.67]	[1.40]			[0.15]	
DH	-6.726***			40.125	50.595	-1.066***	34.44%
	[0.74]					[0.25]	
DI	-20.517***	2.672***	46.462***	37.130	50.540	0.038	103.92%
	[7.69]	[1.02]	[1.73]			[0.03]	
DJ	109.088***	-15.286***	35.452***	32.654	44.282	-0.239**	78.72%
	[15.62]	[2.15]	[0.46]			[0.10]	
DK	238.291***	-31.631***	43.238***	42.191	52.285	-1.214***	29.69%
	[28.20]	[3.66]	[0.53]			[0.16]	
DL	158.070***	-21.402***	40.158***	37.376	49.207	-1.097***	33.37%
	[23.46]	[3.10]	[0.60]			[0.15]	
DM	216.280***	-29.587***	38.665***	38.021	47.109	-1.141***	31.95%
	[32.46]	[4.30]	[0.74]			[0.20]	
DN	-5.226***			28.908	36.109	-1.373***	25.32%
	[0.39]					[0.20]	

Conclusions

- Different performance for **pollutants** and **greenhouse** gases $\Rightarrow$ **ancillary** benefits **not** exploited (**end-of-pipe** technologies for pollutants)
- Role of 2001-2005 (productivity and output) **stagnation**:
  - Reduction of the **scale** (positive effect in the **short** run)
  - **Less** resources for **investments** in environmental efficient technologies (negative effect in the **long** run)
- **SUR** estimates $\Rightarrow$ relevant sector **heterogeneity**

Future research

- Intermediate step ⇒ **energy mix** and energy efficiency
- From Italy to **Europe** ⇒ European **NAMEA**
- Role of **eco-innovation** ⇒ **micro** approach (e.g. survey data)

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