Sector CO_2 and SOx Emissions Efficiency and Investments

Homogeneous vs Heterogeneous Estimates using the Italian NAMEA

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Motivation and objective

- Current **investments** determine the **composition** and the **features** of the **capital** stock for **several years** ⇒ risk of **lock-in** in eco-inefficient technologies ⇒ high **cost** of **restructuring** in the future
- Energy **prices** and environmental **taxes** are likely to influence the **environmental direction** of new investments

1. Which is the environmental direction of the **structural and technological** change experienced by **Italian manufacturing** sectors?
2. Did energy **prices** and environmental **taxes** influence the **direction** of the structural and technological change?

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The role of investments and induced technological change

- Investments and the environment:
  - **Substitution** of obsolete capital stock (+/-)
  - Expansion of the **productive capacity** (+)
  - Role of **ICTs** (+/-) ⇒ see the proceedings of the OECD Conference on 'ICTs, the environment and climate change' (November 2009)
    1. **Direct** effect (production and disposal of ICTs)
    2. ICTs and improvement of the **energy efficiency** of the whole economic system
    3. **Radical changes** in the production system favoured by the use of ICTs
- Role of **energy prices** and **environmental taxes** to **induce** eco-efficient technological change (e.g. Popp, 2002)

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Data sources

- **Emissions** $\Rightarrow$ Italian **NAMEA** (National Accounting Matrix including Environmental Accounts) by **Istat**
  - CO_2, SOx
  - 29 branches disaggregation (Nace Rev. 1.1) $\Rightarrow$ focus on manufacturing
  - 1990-2007
- **Labour** (full-time equivalent jobs) $\Rightarrow$ National accounts by **Istat**
- **Investments** $\Rightarrow$ sector gross investments in **8 categories** of capital goods $\Rightarrow$ National accounts by **Istat**
- **Energy prices** $\Rightarrow$ industry real **price index** and **real** price of **gas**, **oil** and **coal** products $\Rightarrow$ **IEA**
- **Environmental taxes** $\Rightarrow$ **revenue** from environmental taxes as fraction of **GDP** $\Rightarrow$ **Environmental accounts** by **Istat**

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Econometric models I

I estimate the following **equation**:

$$
\ln(E_{st}) = \alpha_s + \sum_i \beta_i \ln(I_{ist-1}) + \delta \ln(L_{st}) + \sum_j \gamma_j Energy\ prices_{jt} +
$$
$$
+ \sum_k \eta_k Env\ tax_{kt} + \varepsilon_{st}
$$

- Gross investment **categories** (5):
    - Machinery, transportation, building, furniture, 'light investments' (ICTs)
- One year **lag**:
    1. New goods enter **gradually** the production process
    2. **Response** of past $(t-1)$ investments to **future** (t) expected **prices/taxes**
    3. Past investments are **predetermined**

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Econometric models II

- Sector full-time equilvalent **jobs**
- **Relative** (to price index) energy industry **prices** for gas, oil and coal
- Real **price index** for industry
- Environmental **taxes** (taxes on **pollution**, **transportation** and **energy**) as fraction of GDP

The model is **estimated**:

1. With **fixed effects** for the full set of **manufacturing sectors** (14) and for the **10 most important emitters** (3-years **time dummies** are included)

2. With **Seemingly Unrelated Regression** method (SUR) allowing for **slope heterogeneity** for the **10 most important emitters** (environmental taxes are excluded)

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FE estimates for CO_2

	Manufacturing (1)	Manufacturing (2)	Main emitters (3)	Main emitters (4)
$\ln(\text{inv\_machinery}_{st-1})$	0.21***	0.23***	0.21***	0.24***
	[0.05]	[0.05]	[0.05]	[0.05]
$\ln(\text{inv\_transportation}_{st-1})$	-0.11***	-0.04	-0.12***	-0.06
	[0.03]	[0.04]	[0.04]	[0.05]
$\ln(\text{inv\_building}_{st-1})$	-0.08***	-0.09***	-0.10***	-0.12***
	[0.03]	[0.03]	[0.03]	[0.03]
$\ln(\text{inv\_furniture}_{st-1})$	-0.01	-0.08**	-0.07*	-0.13**
	[0.02]	[0.03]	[0.03]	[0.05]
$\ln(\text{inv\_'light'}_{st-1})$	0.05	0.06	0.20**	0.21**
	[0.05]	[0.05]	[0.08]	[0.09]
$\ln(L_{st})$	0.70***	0.72***	0.64***	0.68***
	[0.12]	[0.12]	[0.15]	[0.14]
Price coal (rel)$_{st}$	-0.12	-0.37	-0.18	-0.31
	[0.14]	[0.30]	[0.18]	[0.36]
Price oil (rel)$_{st}$	0.22	0.18	0.24	0.32
	[0.22]	[0.32]	[0.25]	[0.38]
Price gas (rel)$_{st}$	0.02	-0.27	-0.14	-0.40
	[0.16]	[0.27]	[0.20]	[0.36]
Energy price index$_{st}$	0.00	0.01	0.01*	0.01*
	[0.00]	[0.00]	[0.00]	[0.00]
Tax on energy$_{st}$	0.05	0.13	0.11	0.19
	[0.07]	[0.13]	[0.09]	[0.16]
Tax on transportation$_{st}$	0.33	-1.32*	-0.10	-1.26
	[0.32]	[0.76]	[0.42]	[0.99]
Tax on pollution$_{st}$	2.74***	4.78	0.68	0.91
	[0.71]	[3.94]	[1.01]	[5.87]
Test time dummies (F)		2.34**		5.12***
F test	9.11***	8.39***	6.81***	5.68***
N	238	238	170	170

FE estimates for SOx

	Manufacturing (1)	Manufacturing (2)	Main emitters (3)	Main emitters (4)
ln(inv_machinery$_{st-1}$)	0.05	0.11	0.17	0.24
	[0.13]	[0.14]	[0.18]	[0.19]
ln(inv_transportation$_{st-1}$)	0.14	0.28**	0.02	0.12
	[0.11]	[0.12]	[0.16]	[0.19]
ln(inv_building$_{st-1}$)	0.16**	0.17**	0.17*	0.18**
	[0.07]	[0.07]	[0.09]	[0.09]
ln(inv_furniture$_{st-1}$)	0.01	-0.19**	0.05	-0.14
	[0.07]	[0.09]	[0.10]	[0.12]
ln(inv_'light'$_{st-1}$)	0.27*	0.23*	0.29	0.26
	[0.14]	[0.13]	[0.18]	[0.17]
ln(L$_{st}$)	0.81**	0.81**	0.95**	0.94**
	[0.36]	[0.34]	[0.41]	[0.41]
Price coal (rel)$_{st}$	0.15	0.76	0.23	0.90
	[0.41]	[0.77]	[0.56]	[1.03]
Price oil (rel)$_{st}$	-0.78	-0.97	-0.81	-0.99
	[0.71]	[0.95]	[0.89]	[1.27]
Price gas (rel)$_{st}$	-1.07**	-0.43	-0.92	-0.38
	[0.45]	[1.03]	[0.60]	[1.39]
Energy price index$_{st}$	0.00	0.01	0.00	0.01
	[0.01]	[0.01]	[0.01]	[0.01]
Tax on energy$_{st}$	1.07***	1.16***	1.09***	1.17**
	[0.18]	[0.41]	[0.23]	[0.54]
Tax on transportation$_{st}$	-3.93***	-5.17**	-3.60***	-4.36
	[0.75]	[2.56]	[1.00]	[3.35]
Tax on pollution$_{st}$	-12.80***	-39.80***	-11.95***	-39.72**
	[2.13]	[12.81]	[2.55]	[17.26]
Test time dummies (F)		3.13***		1.41
F test	98.57***	77.44***	54.36***	40.6***
N	238	238	170	170

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SUR unconstrained estimates for CO_2 (I)

	DA (Food)	DB (Textile)	DE (Paper)	DF (Refineries)	DG (Chemicals)
$\ln(\text{inv\_machin.}_{st-1})$	-0.35	-0.71***	-0.18	-0.01	0.26***
	[0.33]	[0.20]	[0.17]	[0.04]	[0.04]
$\ln(\text{inv\_transp.}_{st-1})$	0.04	0.52***	-0.17*	-0.05	0.23***
	[0.09]	[0.15]	[0.09]	[0.07]	[0.04]
$\ln(\text{inv\_build.}_{st-1})$	0.08	-0.46***	0.20*	0.08*	-0.25***
	[0.13]	[0.11]	[0.10]	[0.04]	[0.03]
$\ln(\text{inv\_furn.}_{st-1})$	-0.09	0.63***	-0.19***	0.03	-0.26***
	[0.10]	[0.12]	[0.06]	[0.02]	[0.04]
$\ln(\text{inv\_'light'}_{st-1})$	0.46**	-0.05	0.37***	0.03	-0.15**
	[0.23]	[0.13]	[0.12]	[0.08]	[0.06]
$\ln(L_{st})$	0.16	-1.37***	-0.44	0.07	0.55***
	[1.07]	[0.41]	[0.51]	[0.31]	[0.08]
P. coal (rel)$_{st}$	-0.68**	-0.33	-0.38**	0.04	0.29***
	[0.28]	[0.25]	[0.16]	[0.18]	[0.08]
P. oil (rel)$_{st}$	0.50	-0.91*	0.48	0.03	0.20
	[0.64]	[0.48]	[0.33]	[0.34]	[0.15]
P. gas (rel)$_{st}$	-0.67	-0.91***	-0.07	0.40	-0.02
	[0.46]	[0.29]	[0.23]	[0.34]	[0.11]
Energy p. index$_{st}$	0.01*	-0.02***	0.01***	-0.01**	-0.01***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Constant	14.73*	32.14***	17.03***	16.48***	14.09***
	[7.96]	[3.53]	[3.47]	[0.87]	[0.75]

Breusch-Pagan test of independence: χ^2=57.394, p-value= 0.1018

SUR unconstrained estimates for CO_2 (II)

	DH	DI	DJ	DK	DM
	(Plastic)	(Non-met. prod.)	(Metal prod.)	(Machinery)	(Transport)
$\ln(\text{inv\_machin.}_{st-1})$	0.15	0.13*	0.14	-0.30***	-0.31*
	[0.09]	[0.07]	[0.11]	[0.11]	[0.17]
$\ln(\text{inv\_transp.}_{st-1})$	-0.15***	0.25***	-0.15**	0.11*	0.15***
	[0.05]	[0.08]	[0.07]	[0.06]	[0.04]
$\ln(\text{inv\_build.}_{st-1})$	0.15***	-0.39***	0.14**	-0.60***	0.33***
	[0.04]	[0.12]	[0.05]	[0.07]	[0.07]
$\ln(\text{inv\_furn.}_{st-1})$	0.32***	-0.12*	-0.17***	-0.29***	0.00
	[0.07]	[0.06]	[0.06]	[0.04]	[0.04]
$\ln(\text{inv\_'light'}_{st-1})$	-0.21**	0.02	-0.38***	0.68***	-1.12***
	[0.10]	[0.10]	[0.08]	[0.14]	[0.29]
$\ln(L_{st})$	1.65***	-0.56	0.46	-0.96**	-0.52**
	[0.29]	[0.41]	[0.34]	[0.38]	[0.26]
P. coal (rel)$_{st}$	0.13	0.08	0.24*	-0.96***	-0.72***
	[0.11]	[0.23]	[0.13]	[0.15]	[0.17]
P. oil (rel)$_{st}$	0.37*	-0.54	0.70**	0.91***	0.13
	[0.22]	[0.39]	[0.29]	[0.32]	[0.28]
P. gas (rel)$_{st}$	0.56***	-0.09	0.17	0.57***	0.24
	[0.19]	[0.20]	[0.21]	[0.20]	[0.16]
Energy p. index$_{st}$	0.01*	0.01**	-0.00	0.00	0.00
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Constant	3.35**	21.49***	15.18***	23.62***	24.74***
	[1.45]	[2.86]	[1.99]	[2.18]	[3.75]

Breusch-Pagan test of independence: χ^2=57.394, p-value= 0.1018

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SUR unconstrained estimates for SOx (I)

	DA	DB	DC	DD	DF
	(Food)	(Textile)	(Leather)	(Wood)	(Refineries)
$\ln(\text{inv\_machin.}_{st-1})$	-1.39***	-2.25***	-0.67**	-3.78***	0.25**
	[0.39]	[0.63]	[0.32]	[0.61]	[0.12]
$\ln(\text{inv\_transp.}_{st-1})$	-0.01	2.23***	0.42*	-0.11	-0.08
	[0.09]	[0.47]	[0.25]	[0.28]	[0.19]
$\ln(\text{inv\_build.}_{st-1})$	-0.68***	-1.92***	0.22	0.32	-0.07
	[0.13]	[0.34]	[0.18]	[0.46]	[0.12]
$\ln(\text{inv\_furn.}_{st-1})$	0.24***	2.22***	0.44***	-0.18	-0.11**
	[0.09]	[0.32]	[0.13]	[0.21]	[0.06]
$\ln(\text{inv\_'light'}_{st-1})$	-0.67***	-0.83**	-0.14	0.92**	-0.40*
	[0.21]	[0.34]	[0.25]	[0.46]	[0.21]
$\ln(L_{st})$	-6.16***	-1.04	5.67***	8.60***	-0.57
	[0.89]	[0.98]	[1.07]	[2.05]	[0.89]
P. coal (rel)$_{st}$	-0.44*	-0.81	0.81	-3.48***	0.96*
	[0.26]	[0.75]	[0.76]	[1.04]	[0.52]
P. oil (rel)$_{st}$	1.36**	-3.85***	0.06	4.14**	0.18
	[0.66]	[1.36]	[1.44]	[1.95]	[0.99]
P. gas (rel)$_{st}$	-1.14**	-2.65***	1.93*	-2.13*	-1.01
	[0.49]	[0.79]	[0.99]	[1.23]	[0.96]
Energy p. index$_{st}$	-0.01**	-0.09***	-0.01	0.01	-0.01
	[0.00]	[0.01]	[0.01]	[0.01]	[0.01]
Constant	66.91***	43.85***	-24.50***	-18.22	14.66***
	[7.09]	[9.38]	[7.69]	[12.04]	[2.61]
Breusch-Pagan test of independence: χ^2=94.960, p-value= 0.0000					

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SUR unconstrained estimates for SOx (II)

	DG (Chemicals)	DH (Plastic)	DI (Non-met. prod.)	DJ (Metal prod.)	DK (Machinery)
$\ln(\text{inv\_machin.}_{st-1})$	0.34	-0.01	0.10***	0.31	0.53*
	[0.31]	[0.60]	[0.04]	[0.36]	[0.28]
$\ln(\text{inv\_transp.}_{st-1})$	-0.85***	-0.23	-0.02	-0.11	0.33**
	[0.27]	[0.37]	[0.05]	[0.20]	[0.14]
$\ln(\text{inv\_build.}_{st-1})$	-0.55***	-0.43*	0.08	-0.04	-0.08
	[0.16]	[0.23]	[0.06]	[0.20]	[0.17]
$\ln(\text{inv\_furn.}_{st-1})$	-0.13	-0.49	-0.02	-0.40**	0.43***
	[0.25]	[0.37]	[0.03]	[0.18]	[0.10]
$\ln(\text{inv\_'light'}_{st-1})$	-1.27***	1.18*	-0.31***	-0.96***	-0.41
	[0.40]	[0.60]	[0.06]	[0.25]	[0.32]
$\ln(L_{st})$	3.30***	-7.83***	1.31***	1.42	-5.60***
	[0.60]	[1.81]	[0.26]	[1.12]	[0.88]
P. coal (rel)$_{st}$	-0.11	-0.43	-0.41***	0.77**	0.21
	[0.58]	[0.84]	[0.15]	[0.37]	[0.43]
P. oil (rel)$_{st}$	2.16**	-1.50	0.02	2.50***	-1.27
	[1.01]	[1.68]	[0.26]	[0.81]	[0.91]
P. gas (rel)$_{st}$	-3.83***	-2.75**	-0.47***	0.66	0.40
	[0.76]	[1.26]	[0.14]	[0.62]	[0.56]
Energy p. index$_{st}$	-0.01	-0.05***	0.01*	-0.01	-0.03***
	[0.01]	[0.01]	[0.00]	[0.01]	[0.01]
Constant	8.12	56.99***	4.73***	4.36	41.63***
	[5.54]	[9.11]	[1.79]	[6.50]	[5.05]

Breusch-Pagan test of independence: χ^2=94.960, p-value= 0.0000

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Conclusions and future research

- High degree of **sector heterogeneity** of the effect of investments on environmental efficiency
- **Investments** are **not** a **good predictor** of **SOx** emissions $\Rightarrow$ SOx emissions are strongly correlated with environmental taxes and the abatement of SOx emissions through **end-of-pipe** devices does **not** require relevant **structural changes**
- **Poor** role of **energy** prices in inducing environmental efficiency $\Rightarrow$ the **volatility** of energy prices creates **uncertainty** about **future** conditions **discouraging** strong **shifts** to different energy regimes or strong improvements of energy efficiency

- **Investments** and energy **prices**/environmental **taxes** are likely to **interact** $\Rightarrow$ explore interactions
- Explore the role of **input-output relations** among sectors in inducing technological change

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