Do Eco-Innovations Harm Productivity Growth through Crowding Out?

Results of an Extended CDM Model for Italy

Giovanni Marin[1]

[1]IMT Institute for Advanced Studies Lucca

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Outline of the paper

- Description of **(eco-)innovation patterns** of **Italian manufacturing** firms, with a specific focus on eco-innovations
- Assessment of the **effect of eco-innovations** on firms' **productivity** $\Rightarrow$ potential **crowding-out**
- Structural empirical model (**CDM model**) to describe innovation patterns at the firm level
- Use of **administrative data** (**balance sheet**, **patent** applications)
- **Bad news** $\Rightarrow$ **crowding out** seems to exist and to be particularly **severe** for **polluting** firms

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Eco-innovations: role and definition

Kemp and Pearson (2007) define eco-innovation as:

> *[...] "the production, assimilation or exploitation of a* **product***, production* **process***,* **service** *or* **management** *or business method that is* **novel to the organisation** *(developing or adopting it) and which results, throughout its* **life cycle***, in a* **reduction** *of* **environmental risk***,* **pollution** *and other* **negative impacts** *of resources use (including energy use) compared to* **relevant alternatives***."*

- Eco-innovation (creation and diffusion) is **crucial** to achieve **sustainability** (together with structural change)
- **Why** should firm **eco-innovate**? $\Rightarrow$ room for environmental **policies**

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Why should eco-innovations crowd out other innovations...

- **R&D** projects are generally **financed** by means of **internal** (limited) financial resources (Hall, 2002) ⇒ high **risk**, **asymmetric** information between entrepreneurs and banks
- R&D performed to obtain **eco-innovations** might **crowd-out general R&D** employed in other (**possibly more profitable**) projects (Popp and Newell, 2009)
- If crowding out occurs, eco-innovations will have a **lower positive effect** on productivity than other innovations or even a **insignificant** or **negative** effect

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...and why not

Porter hypothesis (Porter and Van der Linde, 1995)

- **Policies induce** eco-innovations (**weak** version)
- Policy-induced eco-innovations might have **strong** positive effects on **competitiveness** and, possibly, on measured **productivity** (**strong** version)

1. **Regulation** as a **signal** for **unexploited** resource efficiency and technological possibilities
2. **Regulation reduces the uncertainty** about the value of investments in environmental innovations
3. **Early regulation** in view of future adoption of stringent standards also by competitors might give rise to **first mover advantages**

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CDM model to describe innovation patterns (I)

- The **CDM** (Crepon, Duguet and Mairesse, 1998 NBER WP) model is an **empirical structural model** aimed at describing innovation patterns at the **firm level**
- **Three** steps: (i) determinants of **innovation inputs** (R&D) $\Rightarrow$ (ii) determinants of **innovation output** (product-process innovations, innovative sales, patent applications) $\Rightarrow$ (iii) effect of innovation output on **productivity**
- Sort of **IV approach** to account for endogeneity arising from actual **simultaneity** of firms' decisions and from possible **reverse causality**

CDM model to describe innovation patterns (II)

R&D equation

- Which are the drivers of **innovation (input)** intensity of firms?
- **Few firms report R&D** expenditure ⇒ firms perform formal R&D only if the expected returns pass an **unobservable threshold** ⇒ **Heckman sample selection** model for R&D intensity

Innovation equation(s)

- **Knowledge production function** ⇒ **patent applications count**
- (Predicted) innovation **inputs** (R&D from the first step) and **other factors**
- **Negative Binomial** (NB2) model to account for **overdispersion**

Productivity equation

- Extended **production function** ⇒ (predicted) **patent intensity**
- **OLS** allowing for **non-constant returns to scale**

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Extension to the CDM model

- Distinction between **environmental patent** applications and other applications ⇒ **two** distinct **patent equations** and separate effect on productivity
- Is the **effect** of **eco-innovation** on productivity **homogeneous** for all firms? ⇒ check whether the effect differs systematically for firms with **big polluting plants**?

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Data sources

- **Balance sheet** information from **AIDA** (Bureau van Dijk) for about **73k** Italian **manufacturing** firms in **2000-2007**
- **Patent applications** to the European Patent Office (**EPO**) from PATSTAT (for matching procedure, Marin, 2011) ⇒ about **4k** EPO **applicants** and **18k** EPO **applications** ⇒ environmental patents identified according to their **IPC** class (OECD, WIPO)
- Firms with **polluting plants** were identified through the **E-PRTR** and **EPER** registries for big polluting plants (European Environment Agency)

Description of the samples

- **Exclusion** of very **big** (5000 employees) and very **small** (10 employees) firms
- Exclusion of **outlier** observations
- Focus on **three samples**:
  - **full** sample $\Rightarrow$ **243,293** observations
  - **patent** sample $\Rightarrow$ only observations with positive patent applications $\Rightarrow$ **5,694** observations
  - **polluter** sample $\Rightarrow$ only polluting (EPER, E-PRTR) firms $\Rightarrow$ **6,413** observations

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Some comments on data patents and eco-innovations

Again, **eco-innovation** is **defined** (Kemp and Pearson, 2007) as:

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However, Calel and Dechezlepretre (2012) claim that

> *"economic theory predicts that* **environmental regulations** *would produce* **greater incentive to develop** *new technologies for* **directly regulated firms than for third-party technology suppliers** *because the latter are not discharging emissions themselves and* **receive no private benefit** *from the new technology"*

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Is there a bias?

Table: Probability of filing for an environmental patent (patent sample)

All_env	(1)	(2)	(3)	(4)
Polluter	0.0825***	0.0879***	0.0275*	0.0173
	(0.0186)	(0.0189)	(0.0155)	(0.0149)
Polluting_sector	0.0115	0.00918	0.0322*	0.0437**
	(0.0139)	(0.0137)	(0.0170)	(0.0177)
Polluter	0.0819***	0.0878***	0.0239	0.0124
	(0.0187)	(0.0191)	(0.0154)	(0.0146)
Polluting_sector	0.00320	0.000331	0.0287*	0.0417**
	(0.0134)	(0.0132)	(0.0169)	(0.0177)
Year d.	-	Yes	Yes	Yes
Macro_reg d.	-	Yes	Yes	Yes
Size (ln(L))	-	-	Yes	Yes
Pavitt d.	-	-	Yes	Yes
Class_patent d.	-	-	-	Yes
N	5694	5694	5694	5694

Probit estimates, marginal effects are shown
Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table: First step: R&D equation

	Full sample		Patent		Polluter	
Dep: ln(R&D/L)	OLS	Heckman	OLS	Heckman	OLS	Heckman
ln(L)	-0.0992***	-0.685***	-0.180***	-0.433***	-0.103***	-0.474***
	(0.0142)	(0.0239)	(0.0258)	(0.0340)	(0.0395)	(0.0460)
Market_sh	0.855***	2.516***	0.995*	2.801***	0.215	0.506*
	(0.283)	(0.343)	(0.513)	(0.634)	(0.261)	(0.299)
ln(K/L)	0.128***	0.00818	0.139***	0.102***	0.328***	0.184***
	(0.0126)	(0.0138)	(0.0337)	(0.0380)	(0.0420)	(0.0456)
Constant	-1.319***	3.230***	-0.386*	1.827***	-2.215***	1.781***
	(0.0797)	(0.163)	(0.222)	(0.269)	(0.270)	(0.354)
Selection eq.	Full sample		Patent		Polluter	
ln(L)		0.143***		-0.0758		0.0905**
		(0.0114)		(0.0515)		(0.0357)
Market_sh		-1.847***		-2.081***		-0.350**
		(0.212)		(0.328)		(0.165)
ln(K/L)		-0.0234***		-0.0461**		0.0154
		(0.00585)		(0.0210)		(0.0241)
ln(book_value)		0.426***		0.378***		0.234***
		(0.00987)		(0.0458)		(0.0315)
Age$>$ 10		0.0212*		0.0683		-0.0834**
		(0.0126)		(0.0486)		(0.0388)
Constant		-4.658***		-2.742***		-2.884***
		(0.0568)		(0.243)		(0.157)
Chi sq		1235.0		239.2		284.1
sigma		2.407		2.193		2.492
rho		-0.731		-0.808		-0.803
lambda		-1.758		-1.771		-2.002
Chi sq (rho)		1112.1***		224.1***		201.6***
Log likelihood	-162806.1	-283964.1	-8257.8	-11200.0	-7206.1	-11060.6
N	77470	243293	4052	5694	3415	6413

Standard errors in parentheses; * $p< 0.1$, ** $p< 0.05$, *** $p< 0.01$

Table: Second step: Patent equation (Env = all environmental patents)

	Full sample		Patent		Polluter	
	No_env	Env	No_env	Env	No_env	Env
$ln(\widehat{R\&D/L})$	0.248	0.272	0.328***	0.812***	0.947**	2.421***
	(0.200)	(0.319)	(0.0726)	(0.201)	(0.425)	(0.892)
ln(L)	1.222***	1.215***	0.446***	0.612***	1.315***	1.933***
	(0.131)	(0.207)	(0.0286)	(0.0774)	(0.180)	(0.454)
ln(reg_pat_stock_pc)	0.139	-0.0768	0.159***	-0.213	-0.00723	1.216**
	(0.148)	(0.215)	(0.0602)	(0.155)	(0.407)	(0.497)
Constant	-9.629***	-10.70***	-2.578***	-4.012***	-9.560***	-20.34***
	(0.986)	(1.482)	(0.373)	(0.935)	(2.329)	(3.687)
Chi sq	3152.1	701.4	1164.2	207.3	430.3	2013.8
alpha	10.43	28.38	0.245	3.898	11.01	14.40
Log likelihood	-27620.1	-3807.6	-9457.4	-2252.6	-2086.0	-428.6
N	243293	243293	5694	5694	6413	6413

Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table: Third step: productivity equation (separate effect for **env** and **no_env**)

	Full sample		Patent		Polluter	
Dep: ln(VA/L)	(1)	(2)	(1)	(2)	(1)	(2)
ln(K/L)	0.1184***	0.1215***	0.1028***	0.1028***	0.194***	0.211***
	(0.0013)	(0.0013)	(0.0067)	(0.0072)	(0.0082)	(0.0071)
$ln(\widehat{no\_env/L})$	0.3868***		0.4114***		0.0688***	
	(0.0112)		(0.0672)		(0.0253)	
$ln(\widehat{env/L})$		0.0266***		0.1449***		-0.0154***
		(0.0049)		(0.0289)		(0.0053)
ln(L)	0.0052***	0.0356***	0.3075***	0.1273***	0.046***	0.0357***
	(0.0019)	(0.0017)	(0.0455)	(0.0196)	(0.0048)	(0.0042)
Constant	6.4556***	3.5538***	3.9348***	4.0052***	3.610***	2.885***
	(0.0926)	(0.0514)	(0.0906)	(0.1254)	(0.2071)	(0.0685)
R sq	0.2109	0.2021	0.1814	0.1792	0.3215	0.3217
F	1662.51	1589.53	56.64	55.88	123.09	120.94
N	243293	243293	5694	5694	6413	6413

Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table: Third step: productivity equation (Env = all environmental patents)

	Full sample		Patent		Polluter
Dep: ln(VA/L)	(1)	(2)	(1)	(2)	(1)
ln(K/L)	0.117***	0.115***	0.0975***	0.0975***	0.198***
	(0.00133)	(0.00133)	(0.00724)	(0.00708)	(0.00836)
$ln(\widehat{no\_env}/L)$	0.420***	0.433***	0.328***	0.303***	0.0676***
	(0.0131)	(0.0132)	(0.0807)	(0.0802)	(0.0253)
$\widehat{ln(env/L)}$	-0.0308***	-0.0455***	0.0824**	0.0733**	-0.0152***
	(0.00552)	(0.00568)	(0.0347)	(0.0351)	(0.00534)
$\widehat{ln(env/L)} \times$ polluter		-0.0183*		-0.0383**	
		(0.0101)		(0.0183)	
polluter		-0.0521		-0.228	
		(0.0997)		(0.139)	
ln(L)	0.00510***	0.000740	0.307***	0.280***	0.0421***
	(0.00194)	(0.00196)	(0.0465)	(0.0472)	(0.00493)
Constant	6.409***	6.377***	4.156***	4.111***	3.439***
	(0.0924)	(0.0925)	(0.128)	(0.130)	(0.221)
Net effect for polluter		-0.0639***		0.0340	
		(0.0109)		(0.0396)	
R sq	0.211	0.214	0.183	0.184	0.322
F	1564.6	1413.6	54.97	55.88	113.0
N	243293	243293	5694	5694	6413

Standard errors in parentheses; * $p< 0.1$, ** $p< 0.05$, *** $p< 0.01$

Conclusions

- **Innovation output** of Italian **polluting** firms and sectors is significantly **biased** towards environmental innovations as opposed to other firms and sectors
- The **effect** of **usual drivers** of innovation output **differs systematically** between **environmental** innovations and other innovations
- **Environmental innovations** generally have **insignificant or negative effect on productivity** while other innovations have a strong positive effect $\Rightarrow$ **crowding out?**
- Crowding out is **more severe** for **polluting** firms

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THANK YOU FOR YOUR ATTENTION

Table: Distribution by sector

Sector	Full sample	Patent sample	Perc w/pat	Polluter sample	Perc pollut
DA (food & beverage)	18245	88	0.48%	348	1.91%
DB (textile)	19812	135	0.68%	283	1.43%
DC (leather)	8115	67	0.83%	81	1.00%
DD (wood)	6212	23	0.37%	78	1.26%
DE (paper & printing)	15434	103	0.67%	481	3.12%
DF-DG (petro-chemical)	11082	520	4.69%	1058	9.55%
DH (rubber & plastic)	14173	465	3.28%	181	1.28%
DI (non-metalic mineral prod.)	14461	111	0.77%	849	5.87%
DJ (basic metal prod.)	52915	942	1.78%	2244	4.24%
DK (machinery & equipment)	35990	1843	5.12%	216	0.60%
DL (electrical & optical)	21657	914	4.22%	187	0.86%
DM (transport equipment)	6698	227	3.39%	127	1.90%
DN (manuf. n.e.c.)	18499	256	1.38%	280	1.51%
Scale intensive manufacturing	88946	1752	1.97%	3452	3.88%
Science based manufacturing	26006	1110	4.27%	1192	4.58%
Specialized suppliers manufacturing	42024	2160	5.14%	218	0.52%
Supplier dominated goods	86317	672	0.78%	1551	1.80%
Total	243293	5694	2.34%	6413	2.64%

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Table: Descriptive statistics

Variable	Mean	Q1	Median	Q3	Min	Max	SD/mean
Full sample							
Book value	13478	1800	3608	8392	113.7	7795221	5.36
Employees	63.8	15	26	50	10	4985	2.919
Fixed physical assets per employee	37.41	9.144	22.49	47.64	.6339	472.5	1.228
Value added per employee	47.21	33.23	41.32	54.21	10.2	237.2	.4831
Age	20.05	11	18	26	0	107	.6629
Market share	0.0077	0.0005	0.0013	0.0039	0	1	4.5426
R&D per employee	1.937	.08979	.3252	1.198	2.18e-06	529.7	4.193
Perform R&D (d.)	.3184	0	0	1	0	1	1.463
Regional patent stock pc	.539	.3602	.5676	.7812	.01131	.8801	.4869
Patent sample							
Total patents	2.092	1	1	2	1	44	1.461
Environmental patents (all)	.1507	0	0	0	0	25	4.498
Pollution and waste patents	.03548	0	0	0	0	3	6.057
Renewable energy patents	.04689	0	0	0	0	25	8.895

Extended CDM - Pollution and waste

Table: Second step: Patent equation (Env = pollution and waste patents)

	Full sample		Patent		Polluter	
	No_env	Env	No_env	Env	No_env	Env
$\ln(\widehat{R\&D/L})$	0.267	-0.279	0.352***	0.329	1.006**	0.411
	(0.201)	(0.364)	(0.0731)	(0.294)	(0.420)	(1.132)
ln(L)	1.236***	0.731***	0.457***	0.293***	1.345***	0.834*
	(0.132)	(0.217)	(0.0285)	(0.109)	(0.181)	(0.502)
ln(reg_pat_stock_pc)	0.108	0.417	0.134**	0.243	-0.0213	3.113**
	(0.143)	(0.372)	(0.0590)	(0.283)	(0.411)	(1.314)
Constant	-9.457***	-12.47***	-2.430***	-6.309***	-9.593***	-25.98***
	(0.962)	(2.206)	(0.361)	(1.665)	(2.336)	(7.394)
Chi sq	3193.5	383.8	1297.4	55.89	448.3	3907.3
alpha	10.36	46.33	0.238	6.530	11.21	0.825
Log likelihood	-28627.1	-1313.1	-9605.4	-839.7	-2173.2	-122.8
N	243293	243293	5694	5694	6413	6413

Standard errors in parentheses; * $p< 0.1$, ** $p< 0.05$, *** $p< 0.01$

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Extended CDM - Pollution and waste

Table: Third step: productivity equation (Env = pollution and waste patents)

	Full sample		Patent		Polluter
Dep: ln(VA/L)	(1)	(2)	(1)	(2)	(1)
ln(K/L)	0.115***	0.114***	0.101***	0.0994***	0.194***
	(0.00136)	(0.00135)	(0.00689)	(0.00680)	(0.00823)
$ln(\widehat{no\_env}/L)$	0.598***	0.612***	0.358***	0.291***	0.0687***
	(0.0266)	(0.0283)	(0.0672)	(0.0690)	(0.0243)
$ln(\widehat{env}/L)$	-0.0797***	-0.0873***	0.0671***	0.0941***	0.00434
	(0.00899)	(0.00977)	(0.0246)	(0.0266)	(0.00385)
$ln(\widehat{env}/L) \times$ polluter		0.0562***		-0.0428***	
		(0.0114)		(0.0147)	
polluter		0.757***		-0.321**	
		(0.134)		(0.138)	
ln(L)	-0.0155***	-0.0202***	0.325***	0.296***	0.0473***
	(0.00302)	(0.00303)	(0.0467)	(0.0473)	(0.00498)
Constant	7.241***	7.286***	4.160***	4.234***	3.654***
	(0.132)	(0.136)	(0.136)	(0.141)	(0.215)
Net effect for polluter		-0.0311***		0.0513**	
		(0.0143)		(0.0248)	
R sq	0.213	0.214	0.183	0.186	0.322
F	1564.1	1413.2	56.70	58.26	118.1
N	243293	243293	5694	5694	6413

Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Extended CDM - Renewable energy

Table: Second step: Patent equation (Env = renewable energy patents)

	Full sample		Patent		Polluter	
	No_env	Env	No_env	Env	No_env	Env
$ln(\widehat{R\&D/L})$	0.265	0.108	0.343***	1.126***	0.870**	3.106**
	(0.200)	(0.366)	(0.0724)	(0.287)	(0.417)	(1.321)
ln(L)	1.233***	1.023***	0.454***	0.620***	1.282***	2.091***
	(0.132)	(0.222)	(0.0284)	(0.109)	(0.179)	(0.662)
ln(reg_pat_stock_pc)	0.135	-0.563*	0.158***	-0.745***	0.0393	1.539
	(0.144)	(0.300)	(0.0584)	(0.245)	(0.407)	(0.945)
Constant	-9.607***	-8.051***	-2.566***	-2.149	-9.591***	-42.82***
	(0.966)	(1.963)	(0.359)	(1.587)	(2.314)	(5.788)
Chi sq	3183.7	1297.7	1279.8	664.0	405.5	-
alpha	10.23	54.95	0.232	8.721	11.19	1.115
Log likelihood	-28606.7	-1457.4	-9573.2	-933.4	-2184.7	-129.5
N	243293	243293	5694	5694	6413	6413

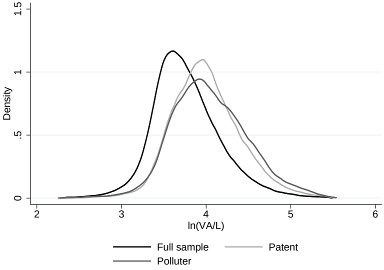
Standard errors in parentheses; * $p< 0.1$, ** $p< 0.05$, *** $p< 0.01$

Extended CDM - Renewable energy

Table: Third step: productivity equation (Env = renewable energy patents)

	Full sample		Patent		Polluter
Dep: ln(VA/L)	(1)	(2)	(1)	(2)	(1)
ln(K/L)	0.118***	0.116***	0.101***	0.0985***	0.186***
	(0.00134)	(0.00133)	(0.00685)	(0.00674)	(0.00853)
$ln(\widehat{no\_env/L})$	0.354***	0.347***	0.432***	0.394***	0.114***
	(0.0112)	(0.0109)	(0.0692)	(0.0726)	(0.0338)
$ln(\widehat{env/L})$	-0.0119**	-0.0181***	0.00603	0.0130	0.00403***
	(0.00555)	(0.00472)	(0.0125)	(0.0140)	(0.00118)
$ln(\widehat{env/L}) \times$ polluter		0.0131*		-0.00765	
		(0.00737)		(0.0138)	
		0.266***		-0.00812	
		(0.0849)		(0.127)	
ln(L)	0.00654***	0.00293	0.325***	0.302***	0.0507***
	(0.00192)	(0.00193)	(0.0452)	(0.0467)	(0.00528)
Constant	6.046***	5.935***	3.974***	3.975***	4.030***
	(0.126)	(0.114)	(0.0956)	(0.0956)	(0.271)
Net effect for polluter		-0.0050		0.0053	
		(0.0076)		(0.0151)	
R sq	0.211	0.213	0.182	0.184	0.323
F	1565.4	1413.8	54.38	51.92	116.4
N	243293	243293	5694	5694	6413

Standard errors in parentheses; * $p< 0.1$, ** $p< 0.05$, *** $p< 0.01$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2
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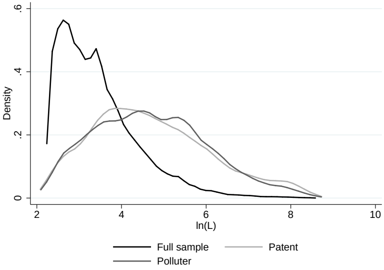
ln(VA/L)
Full sample
Patent
Polluter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Full sample
Patent
Polluter