Do Eco-Innovations Harm Productivity Growth through Crowding Out?

Results of an Extended CDM Model for Italy

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Outline of the paper

- Description of **(eco-)innovation patterns** of **Italian patenting** 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)
- **Evidence** of **crowding out**, particularly **severe** for **polluting** firms and sectors

Eco-innovation and crowding-out

- **Technological change** and eco-innovation are **crucial** to address **environmental issues**
- **Eco-innovation** ⇒ innovations characterized by (**wanted** or **unwanted**) an **improvement** in **environmental performance** compared to relevant alternatives (Kemp and Pearson, 2007)

- 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

- **Porter hypothesis** (Porter and Van der Linde, 1995) ⇒ under certain **conditions** (uncertainty, asymmetric information, etc) policies triggering **environmental innovations** promote might have strong **positive effects on competitiveness**

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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** to describe innovation patterns at the **firm level**
- Determinants of **innovation inputs** (R&D) $\Rightarrow$ determinants of **innovation output** (product-process innovations, innovative sales, patent applications) $\Rightarrow$ 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)

The model is composed by three distinct stages:

- **R&D** equation
- **Innovation** equation(s) (knowledge production function)
- **Productivity** equation

R&D equation

- Which are the drivers of **innovation (input)** intensity of firms? ⇒ firm **size**, **capital** intensity, **age**, **market share**, sector and time **fixed effects**
- **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

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CDM model to describe innovation patterns (III)

Innovation equation(s)

- **Knowledge production function** ⇒ introduction of innovations (dummy), share of innovative sales, patent applications (count variable) ⇒ **patent applications count**
- (Predicted) innovation **inputs** (R&D from the first step) and **other factors** (**size**, local **knowledge stock**, sector and time **fixed effects**)
- **Poisson** and **Negative Binomial** models (to account for **overdispersion**)

Productivity equation

- Extended **production function** ⇒ (predicted) **patent intensity**, **capital** intensity, sector and time **fixed effects**)
- **OLS** with sector and time fixed effects, 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 differ systematically for firms with **large combustion plants** ('polluter') or for **emission - intensive sectors** ('polluting sectors')

Data

- **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 mainly through the **E-PRTR** registry for Large Combustion Plants by the European Environment Agency

- Focus on **firm/year pairs** with **positive patent** applications ⇒ problem of **excess zeros** in count models
- **Selection bias** ⇒ results on the **full sample** are qualitatively very **similar**
- **Exclusion** of very **big** (2000 employees) and very **small** (5 employees) firms and exclusion of **outlier** observations ⇒ **5582** observations

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Table: First step: R&D equation

Dep: ln(R&D/L)	OLS	Heckman
ln(L)	-0.237***	-0.548***
	(0.0291)	(0.0378)
Market share	1.794***	3.058***
	(0.633)	(0.789)
ln(K/L)	0.129***	0.115***
	(0.0324)	(0.0352)
Constant	-0.115	2.293***
	(0.230)	(0.280)
First step Heckman		
ln(L)		-0.0146
		(0.0440)
Market share		-1.712***
		(0.387)
ln(K/L)		-0.0800***
		(0.0214)
ln(book value)		0.405***
		(0.0407)
Age		0.000713
		(0.00146)
Constant		-3.163***
		(0.220)
Chi sq		282
Sigma		2.174
Rho		-0.805
Chi sq Rho		237
P-value Rho		1.75e-53
Lambda		-1.749
log likelihood		-10680.6
N	3857	5582

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

	Poisson			NB		
Dep: patent count	Tot	No-env	Env	Tot	No-env	Env
ln(R&D/L)*	0.395***	0.376***	0.430***	0.424***	0.387***	0.729***
	(0.0664)	(0.0666)	(0.119)	(0.0748)	(0.0714)	(0.237)
ln(L)	0.491***	0.475***	0.561***	0.490***	0.467***	0.648***
	(0.0384)	(0.0388)	(0.0744)	(0.0406)	(0.0389)	(0.124)
ln(stock prov. pc)	0.0127	0.00968	0.0366	0.00781	0.00543	0.00751
	(0.00875)	(0.00845)	(0.0328)	(0.0077)	(0.00758)	(0.0296)
ln(stock reg. pc)	0.159***	0.162***	0.0909	0.134***	0.145***	-0.0535
	(0.0556)	(0.0569)	(0.184)	(0.0503)	(0.0519)	(0.171)
Polluter			0.605***			0.555***
			(0.211)			(0.169)
Polluting sector			-0.0388			0.124
			(0.188)			(0.173)
Constant	-2.833***	-2.844***	-5.696***	-2.691***	-2.699***	-5.397***
	(0.405)	(0.422)	(1.085)	(0.367)	(0.380)	(1.158)
Pseudo R sq	0.103	0.0956	0.0685	0.0718	0.0675	0.0398
Chi sq	546.0	520.9	156.0	707.3	663.6	128.9
Alpha				0.17	0.174	4.204
log likelihood	-9337.1	-9076.2	-2427.3	-8927.3	-8736.8	-2144.3
N	5582	5582	5582	5582	5582	5582

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

Dep: ln(VA/L)	(1)	(2)	(3)	(4)
ln(K/L)	0.0978***	0.0977***	0.0976***	0.0980***
	(0.00750)	(0.00750)	(0.00741)	(0.00748)
ln(L)	0.343***	0.398***	0.379***	0.394***
	(0.0552)	(0.0575)	(0.0562)	(0.0572)
ln(Patent_tot*/L)	0.449***			
	(0.0757)			
ln(Patent_no_env*/L)		0.537***	0.535***	0.526***
		(0.0801)	(0.0772)	(0.0796)
ln(Patent_env*/L)		-0.0146	-0.0322	-0.00367
		(0.0190)	(0.0222)	(0.0194)
Polluter			-0.0681**	
x ln(Patent_env*/L)			(0.0287)	
Polluter			-0.401**	
			(0.203)	
Polluting_sect				-0.0507***
x ln(Patent_env*/L)				(0.0171)
Polluting_sect				-0.356***
				(0.115)
Constant	3.975***	4.014***	3.955***	4.064***
	(0.0912)	(0.117)	(0.123)	(0.121)
Net effect on polluter /			-0.1002***	-0.0543**
polluting sectors			(0.0340)	(0.0247)
R sq	0.156	0.158	0.160	0.159
F	69.40	64.79	58.20	57.53
N	5582	5582	5582	5582

Conclusions

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

Figure: Kernel distribution of log of employees count (firms with positive patents vs all firms)

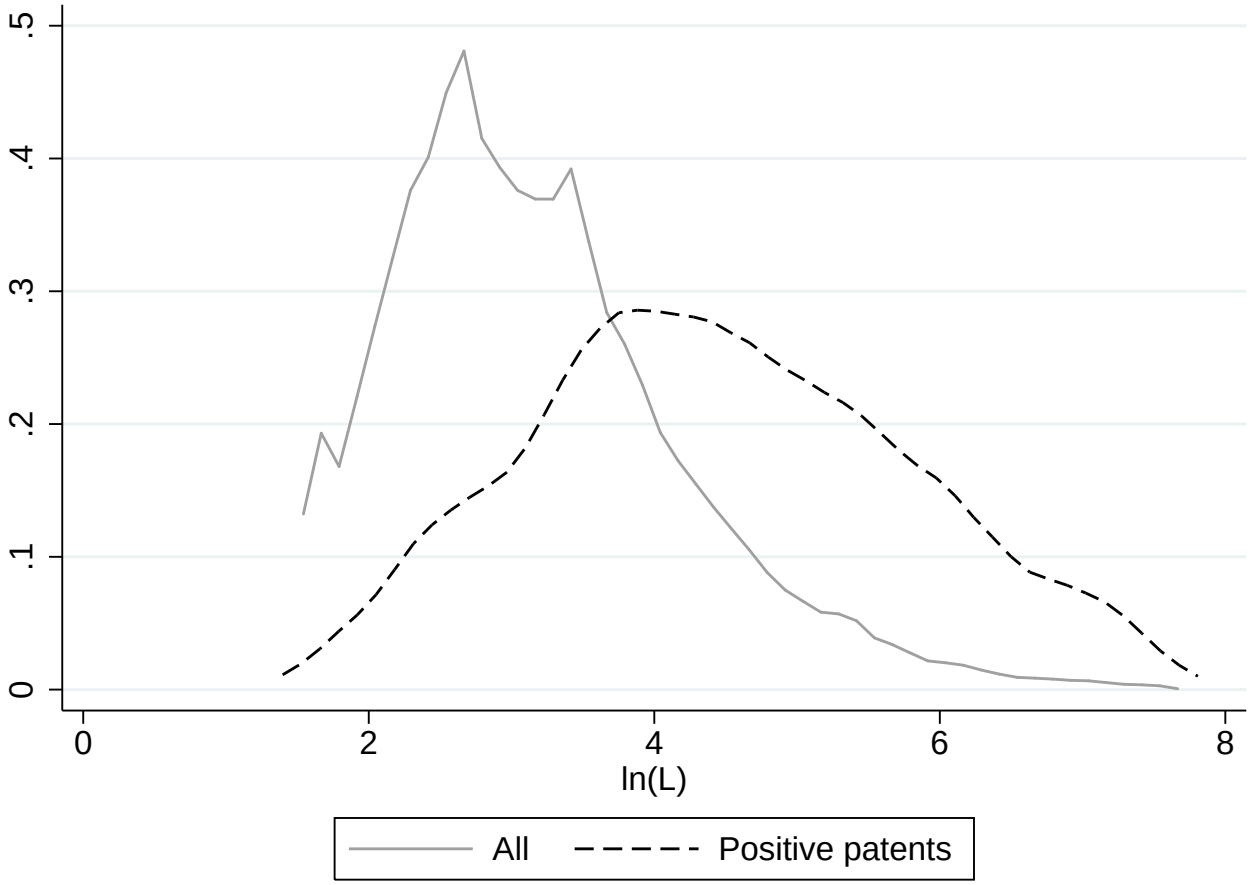

Figure: Kernel distribution of log of value added per employee (firms with positive patents vs all firms)

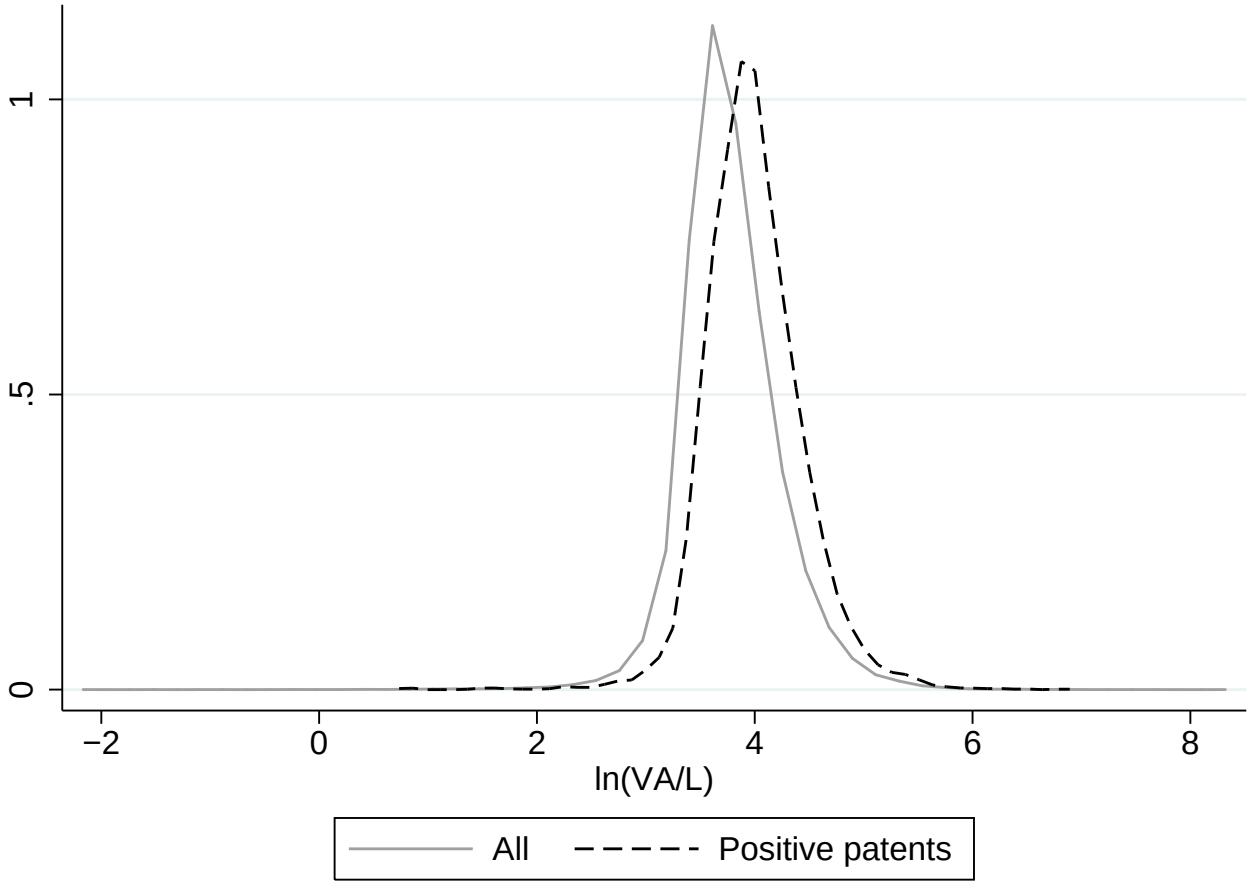

Table: Second step: Patent equation (other sub-categories of env. patents)

Dep: patent count	OECD: no-env	OECD: env	Poll: no-env	Poll: env	Ren: no-env	Ren: env
ln(R&D/L)*	0.417***	0.629**	0.421***	0.296	0.415***	0.938**
	(0.0752)	(0.275)	(0.0751)	(0.270)	(0.0745)	(0.376)
ln(L)	0.488***	0.506***	0.491***	0.235	0.485***	0.711***
	(0.0409)	(0.150)	(0.0408)	(0.146)	(0.0405)	(0.199)
ln(stock prov. pc)	0.00474	0.128***	0.00662	0.0701	0.00874	-0.0186
	(0.00783)	(0.0466)	(0.00776)	(0.0543)	(0.00770)	(0.0444)
ln(stock reg. pc)	0.125**	0.467*	0.131**	0.249	0.148***	-0.478*
	(0.0513)	(0.283)	(0.0510)	(0.292)	(0.0506)	(0.262)
Polluter		0.103		0.528**		0.309
		(0.244)		(0.250)		(0.264)
Polluting sector		0.568**		0.597**		-0.0193
		(0.257)		(0.280)		(0.318)
Constant	-2.647***	-9.093***	-2.699***	-6.249***	-2.786***	-4.115**
	(0.372)	(1.803)	(0.371)	(1.768)	(0.368)	(1.891)
Pseudo R sq	0.0703	0.0385	0.0713	0.0218	0.0708	0.0421
Chi sq	696.5	76.15	709.5	41.52	713.7	60.56
Alpha	0.178	6.857	0.178	7.162	0.169	10.27
log likelihood	-8881.9	-1015.2	-8903.7	-799.7	-8861.8	-903.6
N	5582	5582	5582	5582	5582	5582

Table: Third step: productivity equation (other sub-categories of env. patents)

Dep: ln(VA/L)	OECD: no-env	OECD: env	Poll: no-env	Poll: env	Ren: no-env	Ren: env
ln(K/L)	0.0956***	0.0972***	0.0967***	0.0986***	0.0970***	0.0984***
	(0.00749)	(0.00757)	(0.00746)	(0.00751)	(0.00745)	(0.00751)
ln(L)	0.395***	0.399***	0.325***	0.345***	0.352***	0.366***
	(0.0604)	(0.0611)	(0.0569)	(0.0567)	(0.0550)	(0.0554)
ln(Patent_no_env*/L)	0.582***	0.580***	0.528***	0.502***	0.489***	0.499***
	(0.0905)	(0.0929)	(0.0841)	(0.0863)	(0.0765)	(0.0776)
ln(Patent_env*/L)	-0.0490***	-0.0433**	-0.0754***	-0.0341	-0.0191	-0.0116
	(0.0178)	(0.0201)	(0.0248)	(0.0280)	(0.0136)	(0.0132)
Polluter	-0.0522**		-0.0512*		-0.0536**	
x ln(Patent_env*/L)	(0.0253)		(0.0269)		(0.0253)	
Polluter	-0.382*		-0.337		-0.391*	
	(0.217)		(0.229)		(0.216)	
Polluting_sect		-0.0363**		-0.0406***		-0.0440***
x ln(Patent_env*/L)		(0.0142)		(0.0148)		(0.0154)
Polluting_sect		-0.269**		-0.312***		-0.376***
		(0.110)		(0.117)		(0.126)
Constant	3.866***	3.886***	3.771***	3.911***	3.948***	3.995***
	(0.108)	(0.120)	(0.117)	(0.131)	(0.108)	(0.110)
Net effect on polluter /	-0.1012***	-0.0796***	-0.1266***	-0.0748**	-0.0727***	-0.0556***
polluting sectors	(0.0308)	(0.0235)	(0.0366)	(0.0316)	(0.0266)	(0.0188)
R sq	0.159	0.159	0.159	0.158	0.159	0.158
F	58.50	57.54	58.33	57.61	57.94	57.35
N	5582	5582	5582	5582	5582	5582