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Environmental Innovations and Organizational Change: Is Complementarity a Firm's Asset in the Green Economy?

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Abstract

Along the line of the Porter hypothesis, firm's might react to and challenge environmental policy in a forward looking way. This needs a full restructuring of firm's assets, technologies and competencies. We empirically show through a bivariate probit analysis of environmental innovations (EI) drivers that manufacturing firms that are subject to more stringent policies might use complementarity between organizational strategies to enhance the adoption of EI more extensively.

Keywords: Complementarity, environmental innovations, human resource management, organizational change.

JEL: L6; M53; O3; Q55

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1. Introduction

The role of high performance work practices (HPWP) and Human Resource Management (HRM) are contents of organizational change that might integrate with green business strategies, enriching the realm of the 'Porter paradigm of change' and new competitive advantage (Ambecand Barla, 2006; Costantini and Mazzanti, 2012). We investigate whether manufacturing firms in a major EU country integrate environmental innovation (EI) adoptions (Horbach, 2008) to structural mechanisms of organizational change. We analyze how the complementarity between different performance oriented strategies such as training and organizational innovations of labor and production can jointly foster the adoption of EI.

EI is defined as 'the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (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' (Kemp, 2010, p.2).

It is worth spending some words on the definition of organizational changes, at least as we intend them here. The literature often adopts the term High Performance Workplace Practices (HPWP) to define a set of organizational changes which can be thought as drivers of superior innovative or economic performances for the firm. Coupled with this set of practices that are related to changes in production organization (e.g autonomous or semi-autonomous teams, quality circles) and labor organization (e.g. job rotation, multitasking, increased workers responsibility), we take into account Human Resource Management (HRM) practices, which are referred to the training activities sphere. The human capital embodied in employees becomes a fundamental resource that sustains and directs the organization's absorptive capacity. It becomes clear the importance of training activities that help generating and accumulating skills and competencies, complementary to HPWP. HPWP and HRM practices, as here intended, are inter-wined firm's components, which, in a process of co-evolution and adaptation, influence each other and impact on firm's innovative performance.

We scrutinize whether firms HPWP and HRM integrated strategies can foster the adoption of EIs. More precisely, our main research question is to examine if a relationship of complementarity (Milgrom and Roberts, 1990,1995; Mohnen and Roller, 2005)exists among these practices when the adoption of EIs is the objective.

We believe that a full integration of EI in firms innovation strategies is possible and needed to turn EI from 'green washing' or 'ancillary' strategies into a key issue in firms redefinition of competitive advantages. Fostering green innovation strategies for growth through adequate policy interventions, and studying the determinants of eco-innovations, is a central issue for the next future of developed countries (OECD, 2011).

In particular we examine whether the implementation of joint HRM and HPWP strategies in fostering the adoption of firms EIs is more evident for manufacturing firms belonging to heavily environmental regulated sectors in many fields such as CO2, emissions and waste. We test both the complementarity between various HRM and HPWP practices as engines of EI, and the potential correlation between EI. Section 2 covers data and the model. Section 3 presents econometric evidence. Section 4 concludes.

2. Concepts, the empirical models and the data

At conceptual level, following Topkis (1998) andMilgrom and Roberts (1990, 1995) we may state that two variables x' and x'' in a *lattice* X are complements if a real-valued function $F(x', x'')$ on the *lattice* X is supermodular in its arguments. That is:

(1) $$F(x' \vee x'') + F(x' \wedge x'') \geq F(x') + F(x'') \ \forall x', x'' \in X.$$

Or, written in a different way:

(2) $$F(x' \vee x'') - F(x') \geq F(x'') - F(x' \wedge x'') \ \forall x', x'' \in X,$$

that is, the change in F from x' (or x'') to the maximum $(x' \vee x'')$ is greater than the change in F from the minimum $x' \wedge x''$ to x'' (or x'): raising one of the variables raises the value of increases in the second variable as well. Supermodularity gives an analytical structure to the idea that "increasing the value of some variables never prevents one from increasing the others as well" (Milgrom and Roberts, 1995, p. 182).
In our specific case we consider the 'Environmental Innovation function' of firm $j\,(EI_j)$ as the firm's objective function and we focus on two HRM/HPWP practices that can affect firm's EI function, $h^{'}$ and $h^{''}$:

(3) $$EI_j = EI_j(h^{'}, h^{''}, \theta_j)\ \forall j.$$

θ_j represents firm's exogenous parameters. Actually, a firm operates in an environment which is characterized by exogenous parameters (such as product market, specific sector's technologies, environmental policy specific to a sector) and one can be interested in how different values of the parameter θ may imply different instances of the firm's decision problem, and hence different firm's optimal choices about EI.

On the empirical side, we here set up as objective function a set of innovation functions, that can be modelled as the following bivariate probit:

Eq(1): $[EI(1)]_i = a_{0i}[Controls] + a_{1i}[HPWP\_D(1)/HRM\_D(1)] + a_{2i}[HPWP\_D(1)/HRM\_D(0)] + a_{3i}[HPWP\_D(0)/HRM\_D(1)] + a_{4i}[HPWP\_D(0)/HRM\_D(0)] + u_i$

Eq(2): $[EI(2)]_i = b_{0i}[Controls] + b_{1i}[HPWP\_D(1)/HRM\_D(1)] + b_{2i}[HPWP\_D(1)/HRM\_D(0)] + b_{3i}[HPWP\_D(0)/HRM\_D(1)] + b_{4i}[HPWP\_D(0)/HRM\_D(0)] + e_i$

where the EI dummy variables enter a probit (bivariate) regressions, the HPWP/HRM variables are capturing the different states of the world. We include them with a value of 1 if the firm has a value higher than the average, 0 otherwise. They thus capture a sort of intensity which must be dichotomized on the basis of the conceptual model.It is worth noting that the constant term is suppressed in order to get coefficients for each state of the world; *i* stand for the *i-th* firm. The two single probit might be related *via* the error terms *u* and *e*. The correlation coefficient ρ relating the two errors is zero if the two probits, and thus the firm decisions to implement the two eco-innovations, are not related. As reported in tab.2 and tab.3 the H_0: ρ=0 is rejected and, thus, there is scope for using bivariate probit instead of single probit estimates.

We exploit survey data for the manufacturing sector of the Emilia-Romagna region in Italy (NUTS 2 level), which accounts for the 20% of the national industrial production (ISTAT, 2010) and about the 9% of the national GDP. It is also one of the two most innovative regions in the Italian context and it is classified as a medium-high innovator region at the EU27 level (Hollander et al, 2009). A leading innovating region of a developed country may represent a good 'laboratory' to test our hypothesis about complementary HPWP/HRM practices on EIs.
The answer to research questions is based on micro level data coming from a unique dataset concerning a sample of 555 manufacturing firms. The information set collected through a structured questionnaire administered to firm's management in 2009refers to the period 2006-2008 andit is even richer than that secured by the Community Innovation Survey we take inspiration from (Horbach et al., 2011). Indeed, it concerns several sets of firms activity spanning issues and themes, such as technological and organizational changes, training activities, environmental innovation and internationalization strategies.
The outcome EI variables stem from a set of questions concerning the EI activities carried out by the firms in 2006-2008: the reduction of energy and material for unit of product (ENERGY), the emissions reduction in terms of CO2 (CO2), the emissions reduction to ameliorate the quality of soil, water and air (EMISS) and, finally, the adoption of procedures like EMAS, ISO14001 (EMASISO). In tab.A1 in Appendix the main variables of interest we here use are shown (EI, HRM, HPWP, and controls).
The use of a bivariate probit analysis is additionallyjustified by the presence of high correlations (tab.1).

*Tab.1: Correlations among EI variables^*

	ENERGY	CO2	EMISS	EMASISO
ENERGY	1			
CO2	0.968	1		
EMISS	0.936	0.968	1	
EMASISO	0.937	0.887	0.927	1

^Tetrachoric correlations for binary variables

3. Bivariate probit analysis: complementarity and correlations

3.1 All manufacturing sectors (555 sampled firms)

Table 2 presents the evidence on the deep scrutiny of very diverse complementarity relationships our data allow. We first note that complementarity, which is often referred to as a potential source of competitiveness, cannot be taken for granted. It is possibly not a low hanging fruit, though restructuring firm's organization in a somewhat radical way – interpreted as investing in all productivity inputs *and* (re)-organizing their synergies – may lead to reachable gains even in the short medium term.

First and most important, sub modularity instead of complementarity is witnessed in the statistical significant cases. One 'couple' of HRM-HPWP strategies appear evidently not integrated with EI, namely investing intensely (more than the average) in upgrading workers competencies through specific training *and* intensely changing the organization of production (e.g. team working, quality circle, job rotation etc..) reduces the likelihood of EI adoption. Why could it be the case? We do not claim this is an organizational failure, the 'non complementarity' evidence simply indicates that jointly taken the factors undermine EI. Complexity of joint adoptions is behind this. It might be the case that taken separately HRM factors correlate to EI as shown by Horbach (2008) and Mazzanti and Zoboli (2009).

We now aim at verifying whether complementarity exists and is different in its effects for the sub sample of heavier and more regulated firms.

Tab.2: Complementarities tests in a discrete setting. Linear restriction on states of the world coefficients from bivariate probit regressions (All Sectors)

		Simoultaneous probit estimates for each couple of Eco-Innovations^											
HPWP_D/HRM_D variables		Eq(1): ENERGY	Eq(2): CO2	Eq(1): ENERGY	Eq(2): EMISS	Eq(1): ENERGY	Eq(2): EMASISO	Eq(1): CO2	Eq(2): EMISS	Eq(1): CO2	Eq(2): EMAS ISO	Eq(1): EMISS	Eq(2): EMAS ISO
(Mean value used for dicotomisation)		Wald test*											
TRAINCOVERAGE_D	ORGPROD_D	0.04	0.03	0.02	0.17	0.01	0.58	1.24	0.05	0.36	0.46	0.28	0.85
Coefficients sum (b1+b4)+(-b2-b3)		≥ 0	≥ 0	≤ 0	≤ 0	≤ 0	≤ 0	≥ 0	≤ 0	≥ 0	≤ 0	≤ 0	≤ 0
TRAINCOVERAGE_D	ORGLAB_D	0.81	1.38	0.57	0.19	0.66	0.07	1.73	0.16	1.27	0.07	0.22	0.04
Coefficients sum (b1+b4)+(-b2-b3)		≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0
TRAINCOMP_D	ORGPROD_D	**6.81*** **	**7.16*** **	**6.21** **	**10.83*** **	**6.38** **	**6.1** **	**6.34** **	**11.65*** **	**6.28** **	**6.72*** **	**10.08*** **	**5.76** **
Coefficients sum (b1+b4)+(-b2-b3)		**≤ 0**	**≤ 0**	**≤ 0**	**≤ 0**	**≤ 0**	**≤ 0**	**≤ 0**	**≤ 0**	**≤ 0**	**≤ 0**	**≤ 0**	**≤ 0**
TRAINCOMP_D	ORGLAB_D	0.15	0.89	0.11	0	0.06	0.68	0.62	0	0.73	1.09	0.02	0.61
Coefficients sum (b1+b4)+(-b2-b3)		≥ 0	≤ 0	≥ 0	≤ 0	≥ 0	≥ 0	≤ 0	≥ 0	≤ 0	≥ 0	≤ 0	≥ 0
TRAININVEST_D	ORGPROD_D	0.7	0.13	54	0	0.39	0.92	0.05	0	0.05	1.62	0	2.02
Coefficients sum (b1+b4)+(-b2-b3)		≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≤ 0	≥ 0
TRAININVEST_D	ORGLAB_D	0.42	1.87	0.39	1.43	0.9	0.19	**3.43***	2.13	**2.98***	0.16	1.71	0
Coefficients sum (b1+b4)+(-b2-b3)		≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	**≥ 0**	≥ 0	**≥ 0**	≥ 0	≥ 0	≥ 0

^ Wald tests on ρs do not accept the H0: ρ=0 for any of the bivariate probit estimates;

* Since we are testing one linear restriction at a time the Chi2 distribution has 1 degree of freedom as the number of the linear restrictions;

Critical values of Chi2(1) distribution: 6.63, 3.84 and 2.71 (***1%, ** 5% and * 10% level of significance respectively); N=555; bivariate probit results are not reported for space constraint, but they are available upon request from the authors.

(b1+b4)+(-b2-b3)≥0 is index of potential supermodularity

(b1+b4)+(-b2-b3)≥0 is index of potential submodularity

3.2 Heavy and more regulated industrial sectors

Regulations pose a burden and incentive for firms in more polluting sectors, that have been among other national policies subject to the EU ETS system since 2005[2]. ETS firms belonging to sectors such as ceramics, metallurgy and paper cardboard (192 firms in or sample) might present signals of idiosyncratic complementarity as a way to proactively tackle the regulation challenge through 'innovation offsets'. Complementarity might generate synergies that help achieving the win win more competitiveness-less pollution type of goal.
We interestingly note in table 3 that in this case complementarity arises only for CO2 abatement. Even within bivariate probit, 3 cases where the hypothesis of non-complementarity cannot be rejected emerge. Among all EI, CO2 is the most radical type of adoption. It is also the more expensive, given it implicitly requires a full reshape of firm energy structure and processes, not only end of pipe filter technologies. In fact, it is strikingly evident from the Italian experience that abating CO2 is relatively more complex for industrial firms (see Figures 1 and 2).
This means, coherently with our expectations, that firms implement complementarity for tackling situations that require a full reshaping of production and organization. It also confirm that abating CO2 is not an incremental type of innovation, since it often needs a full rethinking of firm's processes and strategies. Complementarity links are one key element in this forward looking strategy. As far as our sample of manufacturing firms is concerned, the 'training coverage' and 'organization of production' strategies are those which embed – taken together - more radical type of EI adoptions. Again, complementarity is not easy to achieve. It presents benefits, but also costs that firms which look forward to draw new not easily replicable competitive advantages may perceive worth bearing. It is also a way to generate and protect innovation rents through means that can be alternative to standard R&D investments. In some circumstances, where small medium firms dominate, complementarity is an intangible asset that can compensate for R&D weaknesses (Figure 3).

[2] The EU Emission trading system (ETS) is launched by the 2003 EU Directive. It is the main policy – based on a consolidated economic environmental policy instrument - the EU has implemented to achieve the Kyoto target.

Tab.3: Complementarities tests in a discrete setting. Linear restriction on states of the world coefficients from bivariate probit regressions (Heavy Industrial Sectors)

	Simoultaneous probit estimates for each couple of Eco-Innovations^											
HPWP_D/HRM_D variables	Eq(1): ENERGY	Eq(2): CO2	Eq(1): ENERGY	Eq(2): EMISS	Eq(1): ENERGY	Eq(2): EMASISO	Eq(1): CO2	Eq(2): EMISS	Eq(1): CO2	Eq(2): EMASISO	Eq(1): EMISS	Eq(2): EMASISO
(Mean value used for dicotomisation)	Wald test*											
TRAINCOVERAGE_D ORGPROD_D	0.53	**4.01****	0.54	0.25	0.9	0.29	**5.37****	0.55	**4.95****	0.34	0.13	0.11
Coefficients sum (b1+b4)+(-b2-b3)	≥ 0	**≥ 0**	≥ 0	≥ 0	≥ 0	≥ 0	**≥ 0**	≥ 0	**≥ 0**	≥ 0	≥ 0	≥ 0
TRAINCOVERAGE_D ORGLAB_D	1.31	0.5	1.52	0.24	1.38	2.33	0.55	0.27	0.58	2.12	0.35	2.09
Coefficients sum (b1+b4)+(-b2-b3)	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0
TRAINCOMP_D ORGPROD_D	0.31	1.77	0.28	1.59	0.34	0.27	1.59	1.5	1.6	0.11	1.76	0.08
Coefficients sum (b1+b4)+(-b2-b3)	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0
TRAINCOMP_D ORGLAB_D	0.02	0.25	0	0.04	0.07	0.33	0.16	0.06	0.38	0.35	0.25	0.47
Coefficients sum (b1+b4)+(-b2-b3)	≤ 0	≤ 0	≤ 0	≤ 0	≤ 0	≥ 0	≤ 0	≤ 0	≤ 0	≥ 0	≤ 0	≥ 0
TRAININVEST_D ORGPROD_D	1.74	0.89	1.45	0.3	1.43	1.74	0.9	0.44	1.09	2.31	0.25	2.08
Coefficients sum (b1+b4)+(-b2-b3)	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0
TRAININVEST_D ORGLAB_D	0.15	n.f.	0.51	1.7	0.14	0.04	n.f.	2.04	n.f.	0.02	1.82	0.07
Coefficients sum (b1+b4)+(-b2-b3)	≥ 0	n.f.	≤ 0	≥ 0	≤ 0	≥ 0	n.f.	≥ 0	n.f.	≥ 0	≥ 0	≤ 0

^ Wald tests on ρs do not accept the H0: ρ=0 for any of the bivariate probit estimates;

* Since we are testing one linear restriction at a time the Chi2 distribution has 1 degree of freedom as the number of the linear restrictions;

Critical values of Chi2(1) distribution: 6.63, 3.84 and 2.71 (***1%, ** 5% and * 10% level of significance respectively); N=192; n.f meand 'not feasible' because in the CO2 equation the state of the world TRAININVEST_D/ORGLAB_D (0,1) predict failure perfctly and it is dropped so the coefficient b3 cannot be computed; bivariate probit results are not reported for space constraint, but they are available upon request from the authors.

(b1+b4)+(-b2-b3)≥0 is index of supermodularity

(b1+b4)+(-b2-b3)≥0 is index of submodularity

4. Conclusions

We have used complementarity theory and concepts to analyse the somewhat overlooked potential integration of environmental innovations in the whole structure of HRM and HPWP strategies a firm might implement to achieve new sources of sustainable competitiveness.

On the basis of a rich dataset that deeply goes into diverse firms strategies and covers a relevant EU industrial region, we show that complementarity, though it is not a low hanging fruit firms might easily get to, is a concrete fact which amalgamates competitive oriented elements of a firm strategy.

We sharply present clear evidence on how complementarity also differently applies to all manufacturing firms and more polluting more regulated ones. The average firm seem unable to fully exploit potential complementarity between specific HRM and organization related actions independently of the type of EI adoptions. The small medium sized firms of the industry under study which predominate are one possible cause of the difficulty of purposefully integrating various dimensions of competitive advantage, with EI among them. Linking EI to one specific investment, say training, might be more effective in certain cases.

Nevertheless, narrowing down to more polluting firms in defined sectors, we note that complementarity is emerging and backing specific forms of EI, namely CO2 abatement. This is evidence that shows how potentially complementarity is a firm's asset behind the adoption of process integrated more radical forms of innovation. In such cases, the challenges and incentives posed by stricter regulations and sector related technological idiosyncrasies well explain the different evidence.

Figure 1. Emissions ofSOxNOx CO2. Italy, Industry (data from NAMEA, ISTAT, Rome)

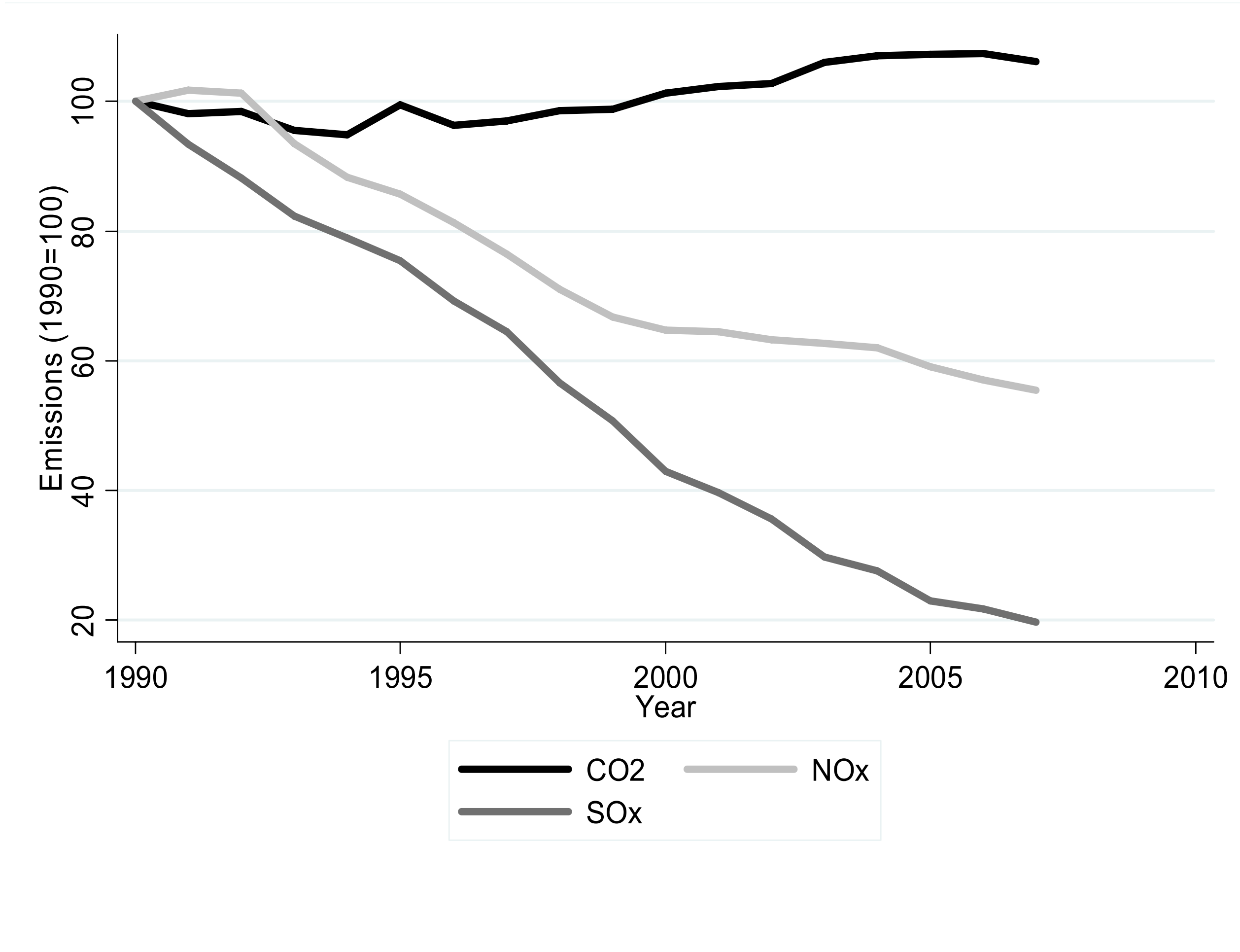


Figure 2. CO_2 trends in the EU (source. Eurostat)

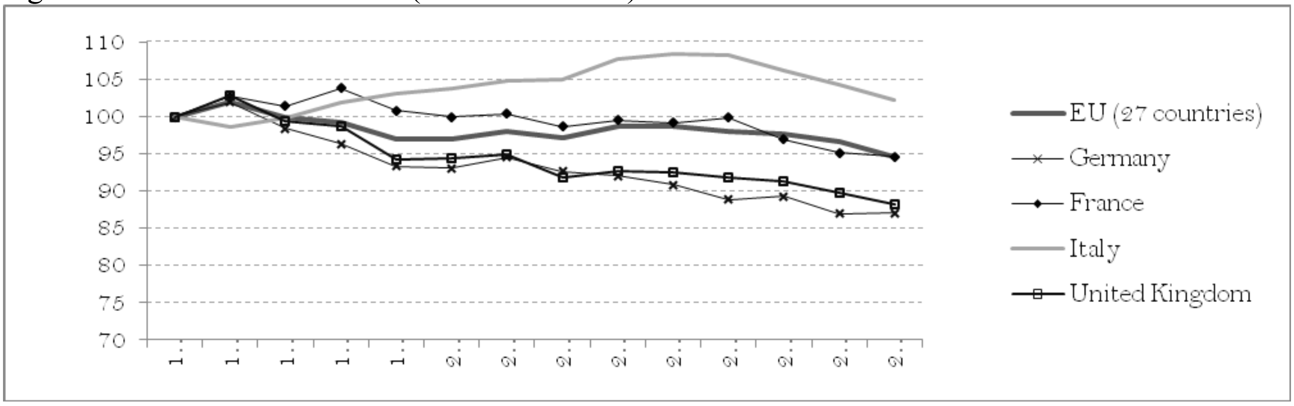
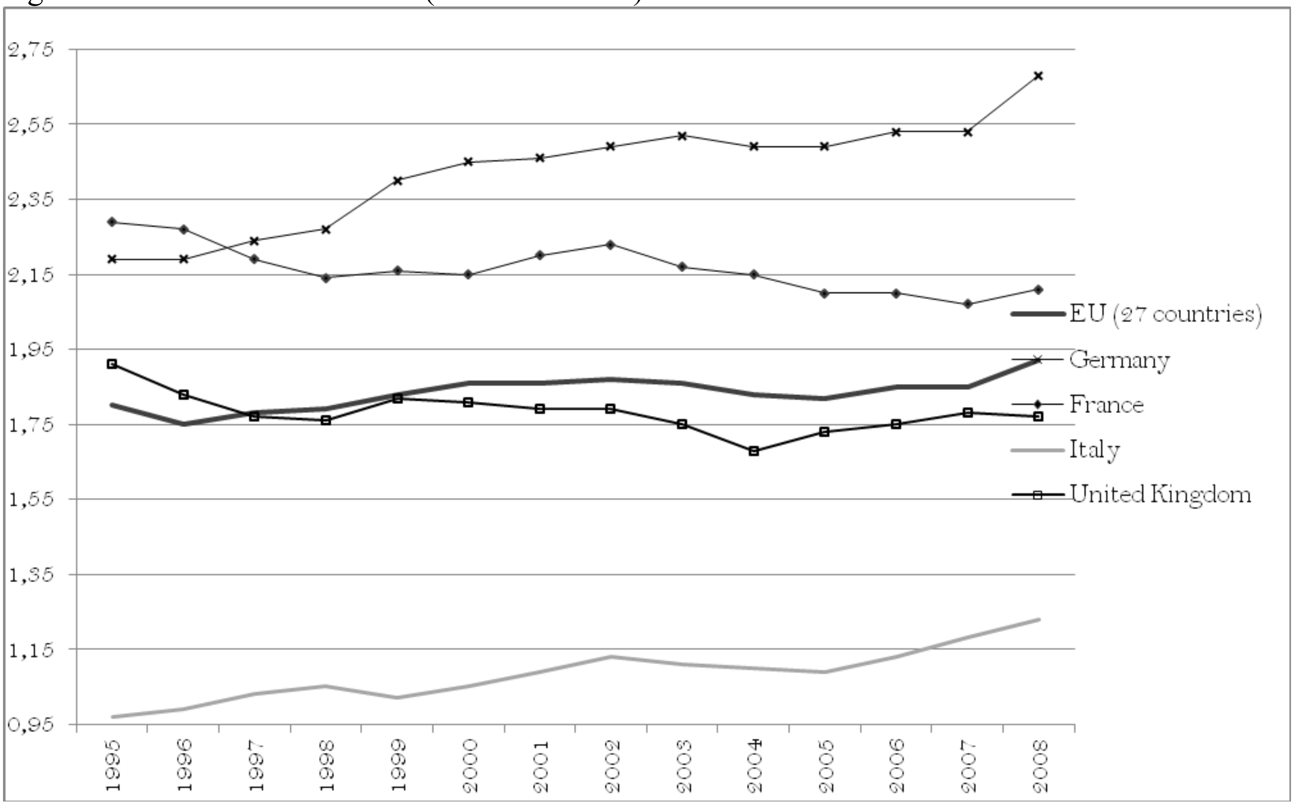


Figure 3. share of R&D on GDP (source Eurostat)



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Appendix

Tab.A1: Descriptive statistics

	Whole sample Mean (555 obs.)	*StDev*	*Min/Max*	*Polluting sectors Mean (192 obs.)*	*StDev*	*Min/Max*
Outcome variables						
Energy/Material reduction per unit of product (**ENERGY**)	0.147	0.355	0/1	0.223	0.417	0/1
CO_2 reduction (**CO2**)	0.115	0.319	0/1	0.171	0.378	0/1
Emissions reduction for soil, water and air (**EMISSIONS**)	0.140	0.347	0/1	0.213	0.410	0/1
Adoption of procedures like EMAS and ISO14001 (**EMASISO**)	0.144	0.351	0/1	0.187	0.391	0/1
HPWP						
Production organisation aspects (ORGPROD_D)	0.631	0.483	0/1	0.661	0.474	0/1
Labour organisation aspects (ORGLAB_D)	0.393	0.489	0/1	0.432	0.497	0/1
HRM						
Employees involved in training activities (TRAINCOVERAGE_D)	0.377	0.485	0/1	0.453	0.499	0/1
Full set of competences covered by training activities (TRAINCOMP_D)	0.105	0.306	0/1	0.094	0.292	0/1
Presence of resources invested in training (TRAININVEST_D)	0.735	0.442	0/1	0.797	0.403	0/1
Controls						
Sector dummies (5 Pavitt/OECD sector dummies:labour intensive (LI), resourceintensive (RI),science based (SB),scaleintensive (SI), specialised suppliers (SS))	/	/	0/1	/	/	0/1
Size dummies (4 size dummies: 20-49 employees; 50-99 emp.; 100-249 emp.; more than 249 emp.)	/	/	0/1	/	/	0/1
INTERN_OPEN	0.021	0.066	0/0.83	0.016	0.053	0/0.33
R&D	0.800	0.400	0/1	0.776	0.417	0/1
TECH_NET	0.101	0.114	0/0.74	0.089	0.108	0/0.74