UNIVERSITÀ DEGLI STUDI DI FERRARA
DIPARTIMENTO DI ECONOMIA E MANAGEMENT
Via Voltapaletto, 11 – 44121 Ferrara

Quaderno DEM 13/2013

May 2013

Information Technology, Environmental Innovations and Complementarity Strategies

Davide Antonioli, Marianna Gilli,
Massimiliano Mazzanti, Francesco Nicolli

Quaderni DEM, volume 2 **ISSN 2281-9673**

INFORMATION TECHNOLOGY, ENVIRONMENTAL INNOVATIONS AND COMPLEMENTARITY STRATEGIES

Davide Antonioli[*]*, Marianna Gilli*[*]*, Massimiliano Mazzanti*[*] *and Francesco Nicolli*[•]

Abstract

The paper investigates the extent to which the adoption of Information and Communication Technology (ICT) by firms affects the likelihood of adopting environmental innovations (EI). We also test empirically whether various types of ICT adoption and other innovation practices (R&D, techno-organizational change) are complementary inputs with respect to the introduction of specific environmental innovations. The analysis is based on two different data sources, which offer various views on ICT and EI relationships. The first draws upon the ICT and environmental innovations information contained in the EU Community Innovation Survey (CIS), the other on an original CIS like survey focusing on a large Italian industrial region, Emilia-Romagna. This survey contains information on the adoption of environmental innovations and some detailed information on ICT issues and other technological-organizational processes. We find that ICT adoption is robustly and positively correlated to EI in the EU. In addition, complementarity is characterizing the relationship between ICT and other innovation processes as a force behind EI, but it is not to be taken for granted. In fact, it appears a robust empirical fact with regard to general innovation capacity (R&D and ICT), though when we narrow down the focus to specific techno-organizational innovations, complementarity with ICT is rarely a pillar firm's green strategies. Further research might focus on the complementarity between ICT and EI as an 'asset' promoting higher economic performances.

Keywords: ICT, environmental innovations, complementarity, organizational change, CIS.

JEL CODE: L60; O30; Q58

[*] University of Ferrara, Department of Economics and Management.

[•] Institute for Economic Research on Firms and Growth, National Research Council (CERIS/CNR) and University of Ferrara, Department of Economics and Management. Corresponding Author: francesco.nicolli@unife.it.

1. The adoption of ICT, Eco innovations and complementarity

The advancement to a greener and more competitive economy is possible only if all components of social welfare are taken into account by firms, stakeholders and policy makers. Environmental innovations (EI) are a key factor, as it is well known that sustainable economic growth depends upon a constant investment in technological, organizational and labour related new ways of managing production. The EI potential must be enriched and embedded within a very broad set of related factors. One of the most recent definitions of eco-innovation defines it as the production, application or use of a product, service, production process or management system new to the firm adopting or developing it, which implies a reduction in environmental impact and resource use (including energy) throughout its life-cycle (Kemp, 2010). This definition includes innovations whose environmental effects are not intentional. A relevant distinction can be made between end-of-pipe technologies and clean technologies integrated in the production process (Del rio, 2009). The analysis of the determinants of eco innovation (EI) has largely developed over the recent years along various streams of research, that have enlarged the vector of eventual correlated factors (De Marchi, 2012; Horbach et al., 2012; Cainelli et al., 2012a,b; Veugelers, 2012) and included the role of complementarity between factors behind EI (Antonioli et al., 2013).

How to spur the adoption of new or significantly improved products or processes, organizational or marketing methods that create environmental benefits by firms and which have to be considered valid determinants of the adoption of such environmental innovations, are central and widely debated topics. On the one side specific firm characteristics such as Sector, Region, Age and Size are found to be significant EI drivers (Rehfeld et.al, 2007; Ziegler and Rennings, 2004). The so called "market pull variables" play a role, such as turnover expectations and economic performance of the past (Horbach 2006, 2008; Mazzanti and Zoboli, 2009, Rehfeld et al., 2007). On the other side also "technology push variables", i.e. those related to improvements in the technological capabilities of firms matter, in particular R&D and/or the presence of knowledge capital and of organizational innovations and management schemes, (mainly ISO 14001 and EMAS) have come to be relevant (Ziegler and Rennings, 2004). Regulation and environmental policies have also found to significantly affect the adoption of environmental innovations (Jaffe and Palmer, 1997; Cleff and Rennings 1999; Brunnermeier and Cohen 2003; Costantini and Mazzanti, 2010; Frondel et. Al, 2004; Horbach e Rennings, 2012 Rennings et. Al, 2006; Jaffe et al., 2002; Johnstone et al., 2012; Rennings and Rexhauser, 2010), although with some mixed results when referred to the European Trading Scheme effects in Italy (Borghesi et.al, 2012).

What is possibly lacking is a full assessment of the links (e.g., searching for complementarities) between EI and 'non EI' innovations and organizational changes, within a broad perspective that enriches EI with links to workers conditions, relationships between the firm and its stakeholders, including the key role of unions. This perspective is crucial to identify successful and unsuccessful EI within the pathway towards the multiple environmental economic and social aspects the green economy should try to bring together. In fact, the definition of EI as noted is not only about specific technologies; it includes also new organizational methods, products, services and knowledge oriented innovations.

The diffusion of information and communication technologies (ICTs) in the society occurred in recent decades caused substantial changes in production processes, behaviors and lifestyles. The effect of ICTs on the environment (in terms of environmental pressures and impacts) has been classified into three classes (OECD, 2010). Direct effects (first order) relate to life cycle environmental pressures (material and energy use, release of emissions, management of end-of-life products) related to the production and use of ICTs. Enabling effects (second order) consist in changes in environmental impacts across all sectors due to the adoption of ICTs. Systemic effects (third order) regard the effect of the adoption and diffusion of ICTs on the behaviors of the society and on lifestyles.

The development of Information and Communication Technologies is important and somewhat overlooked in the context of EI.[1] Berkhout and Hertin (2004), for example, distinguish three environmental effects of (green) ICT: *direct* (pollutant) effects, driven by the larger scale of production and use of activities that ICT allows for; *indirect* effects, due to the dematerialization of introducing ICT in production processes (on the actual extent of these effects, see Montresor and Vittucci, 2011), and the generation of lower environmental impacts; *structural change* effects, linked to behavioural comprehensive effects, and value based changes for firms and households. When data availability permits it, the research hypothesis to target would be whether the more diffuse and intense – not just present – is the ICT adoption in a firm, the more likely is that EI and ICT will be correlated and integrated in the firm's innovative strategy. Direct compensating effects may emerge if innovation adoption increases the firm's turnover and production (Bohringer *et al.*, 2008).

Building upon this framework, the paper originally investigates the extent to which the adoption of ICTs by firms affects the likelihood of adopting environmental innovations. We also test empirically whether various types of ICT adoption, other innovation practices and specific environmental innovations are complementary inputs. The role of ICT adoption as a component of the greening of firm's production has been object of previous research (Cecere et al., 2012), although applied research has been constrained by paucity of data. Among others, Cainelli et al. (2012) find a positive and very high correlation between EI and ICT adoption (namely intensity in the adoption of ICT innovations).

The research strategy of the paper is twofold:

H1 : We investigate the extent to which the adoption of ICTs by firms affects the likelihood of adopting environmental innovations or show econometric based 'correlations' (Nogareda and Ziegler, 2009).

H2 : We test empirically whether various types of ICT adoption and other innovation practices are complementary inputs (Milgrom and Roberts, 1995) with respect to EI.

We use EU CIS data for testing hypothesis 1, and both the CIS and original data from a regional survey to test the complementarity hypothesis. This investigation delivers new EU based evidence on the rather overlooked relationships between EI and ICT. The paper is structured as follows. Section 2 presents the data, section 3 comments on econometric outcomes and section 4 concludes.

2. The data

We exploit two sources of data to analyse the role of ICTs. First, we use the information of the CIS 2006-2008 that includes both ICT and EI questions. Community Innovation Survey (CIS) are a series of surveys produced by the national statistical offices of the 27 European Union member states. The surveys have been implemented since 1993, on a two-yearly basis and are designed to obtain information on innovation

[1] More in general, innovation in ICT has been claimed to stimulate "green" economic growth and spur a recovery from the current global crisis (OECD, 2009).

activities of enterprises, including various aspects of innovation process, as innovation effects, cost and sources of information used. Data are collected at micro level, using a standardized questionnaire developed in cooperation with the EU Member States to ensure the comparability across countries. The sixth CIS (2006-2008) collects data on environmental innovation for the first time. Horbach et al. (2012) present evidence for Germany that 'equipment software' positively affects eco-innovations by using CIS data. We here extend the analysis through an EU coverage (namely Germany, Italy, Portugal and Czech Republic due to data availability on the relevant variables we aim at analysing). We also present evidence of ICT relation to various EI (material, energy, CO2 reductions).

Second, we exploit data from an original survey on a Northern Italian region, Emilia Romagna. The survey was carried out in 2009 to cover the same basic questions on EI presented by the CIS (see Antonioli et al., 2013). The survey covers 555 manufacturing firms for which information on EI and techno-organisational innovations are available. The ICT section is very detailed and provide many information that can be usefully correlated to EI information, that somewhat mirror the CIS taxonomy (carbon abatement, emission abatement, EMS, environmental R&D, etc..). More information on the survey are available in two recent published papers namely Antonioli et al., 2013 and Cainelli et al., 2012 that deal with EI and complementarity issues on such data source); Some evidence of EI-ICT positive correlation is already shown at general level. More detailed analyses could focus on specific elements within the EI and ICT realms, with a strong eye on complementarity and its effects. This might be a way to spur other refined applied research around such issues.

The information on ICT adoption are nevertheless more extended and detailed compared to the EU CIS and offer room for assessing the complementarity between ICT and other techno organizational innovations that may lie behind the adoption of EI. Hall et al. (2012) recently focus on the complementarity between R&D and ICT as a factor associated to innovation adoption. They do not find significant complementarity, though they find complementarity between R&D and worker skill in innovation. Complementarity is a crucial determinant of innovation that may be very relevant to fully integrate EI in production processes while increasing the value of adoption through the integrated inclusion of more innovations.

We test the effect of ICT adoption as defined by the CIS survey in a regression framework that considers a set of EI determinants that covers structural factors (sector, country effects), firm specific factors (size, turnover), innovation inputs (R&D), relational variables (information received by sources external to the firm), market variables (e.g. internationalisation). ICT is included as an additional covariate to test its role in a multivariate setting. Descriptive statistics are presented in sections below.

3. Econometric evidence

To address the research hypothesis number 1 we estimate the following probit model (Horbach, 2008; Cainelli et al., 2012; Veugelers, 2012):

$$\Pr(Y_i = 1/X) = \Phi(X, \beta)$$

Where Φ is the cumulative distribution function of the standard normal distribution and Y_i is a dummy variable that takes the value 1 if a firm *i* introduces an EI and 0 otherwise. X is a set of covariates.

For what concern research hypothesis 2, we study here the complementarity between ICT and firm's techno-organizational strategies through the properties of supermodular functions. This technical approach has the benefit to focus on the pure economic analysis, without the need to dwell on more mathematical issues, such as particular functional forms that ensure the existence of interior optima. For example, no divisibility or concavity assumptions are needed, so that increasing returns are easily encompassed. Following Milgrom and Roberts (1995) we 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, if and only if:

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

Or, written in a different way:

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

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 (see Antonioli et al., 2013; Mancinelli and Mazzanti, 2009 and Mazzanti and Zoboli, 2008 for more methodological details).

3.1 ICT and EI adoption in the EU

The analysis on the EU is based on a firm dataset that derives from the CIS2006-2008 (Tables 2-3 shows the sector and country specifications of the entire dataset with details on the EI variables we investigate, while Table 1 present a brief description of all available variables). We exploit the micro-oriented CD-ROM released by Eurostat[2] (for analysis that use meso data we refer to Gilli et al. (2013). Given the specific outlook of our research, we have restricted the dataset to 5 countries due to data availability for main variables (Table 4). The size and heterogeneity of countries we focus on allows a robust investigation of the EU framework in terms of innovation adoption.

[2] Contract agreeement between EUROSTAT and Department of Economics and Management University of Ferrara, July 2012.

Tab. 1 - Descriptive statistics and description of dependent variables (*) and covariates

	Mean	*Std. Dev*	*Description*
ECOMAT*	0.195	0.396	Innovation in material reduction
ECOEN*	0.234	0.424	Innovation in energy efficiency
ECOCO*	0.180	0.348	Innovation in CO2 abatement
RMAC	0.795	0.404	Acquisition of advanced machinery, eqipment and computer hardware.
MANIF	0.427	0.494	Manufacturing (NACE C10 to C33)
CONSTR	0.124	0.330	Construction (NACE F41 to F43)
UTILITY	0.047	0.211	Utility (NACE D to E)
TRADE	0.113	0.339	Trade (NACE G45 to G47)
OTHER	0.269	0.444	Other services sectors (NACE H49 to N)
SIZE8	0.520	0.725	Firm's size in 2008
TURN08	1,137	2,291	Firms' turnover in 2008 (in millions of euro)
RD	0.047	0.211	Internal and external R&D
FUNLOC	0.113	0.317	Firms that receives public funding from local government
FUNGMT	0.135	0.342	Firms that receives public funding from national government
FUNEU	0.056	0.230	Firms that receives public funding from European Union
MKTINT	0.165	0.371	Firms that operates in local and national markets
MKTEXT	0.084	0.278	Firms that operates in European and other countries' market
DUMMY_SENTG	0.908	0.290	Internal information sources on innovation
DUMMY_SMKT	0.938	0.240	Market information sources on innovation
DUMMY_SINT	0.696	0.460	Institutional information sources on innovation
co	0.280	0.449	Cooperation on innovation activities with other enterprises and institution

Source: Eurostat (cd-rom release of CIS 2006-2008)

Tab. 2 - Distribution of firms by industry (entire CIS dataset)

	N	**%**
Manufacture	16762	42.7
Construction	4866	12.4
Utility	1840	4.7
Trade	5204	13.3
Other services	10574	26.9
Total	39246	100

Tab. 3 - Distribution of ecoinnovative firms by industry

	ECOMAT		ECOEN		ECOCO	
	N	**%**	**N**	**%**	**N**	**%**
Manufacture	4314	64.7	4835	60.4	3387	55.5
Construction	292	4.4	444	5.6	472	7.7
Utility	272	4.1	480	6.0	442	7.2
Trade	396	5.9	535	6.7	450	7.4
Other services	1397	20.9	1706	21.3	1354	22.2
Total	6671	100	8000	100	6105	100

Tab. 4 - Distribution of ecoinnovative firm by country

	ECOMAT		ECOEN		ECOCO	
	N	**%**	**N**	**%**	**N**	**%**
Germany	1843	27.6	2132	26.7	1675	27.4
Italy	1628	24.4	2275	28.4	2021	33.1
Portugal	1811	27.1	1943	24.3	1426	23.4
Czech Republic	1389	20.8	1650	20.6	983	16.1
Total	6671	100	8000	100	6105	100

We present below the main results for the analysis on the EU. We carry out various steps. We first assess the role of ICT (software equipment) as a factor that correlates to EIs in a multivariate setting, namely an innovation function framework (Table 4 shows up all covariates that we initially used, regression tables present only those related to significant coefficients. This 'from general to particular procedure is useful to balance the pros and cons of (i) omitting relevant variables from the analysis – thus inducing biases – and (ii) including irrelevant variables – thus generating inefficiency in estimates). Second, we assess this effect country by country. Third, but not least relevant, we test the complementarity effect of R&D and ICT adoption as a joint factor behind EI adoption (Antonioli et al., 2013; Hall et al., 2012). The complementarity analysis introduces the main issue of results we comment on in section 3.2 that draws upon richer information set for the ICT related variables.

Table 5 shows up the main evidence on the EU (selected countries). ICT (RMAC) strongly correlates with all EI. It is highly noteworthy that the economic effect is larger for what concerns innovation to abate CO2, a relatively more radical kind of EI[3]. This might imply that the integration between EI and ICT is promising and necessary towards the de-carbonization of the economy. Surprisingly, a similar role is played by R&D contrary to the result that was found in other works that commented upon the almost irrelevant role of 'general' R&D for EI (Cainelli et al., 2012). ICT evidently emerges as a key factor here, as well as the set of 'relational-information' factors: cooperation with other agents and other types of information represents effective ways to increase the EI adoption. In order to challenge the sustainability – competitiveness matching, firms must construct various relationships and exploit the knowledge coming from outside the 'boundary of the firm'. It is relevant to note that besides energy efficiency, which was probably more characterized as realm by policies, other external factors of policy and market nature do not impact on EI adoption. CO2 abatement appears to be correlated to only ICT and cooperation (Cassiman and Veugelers, 2002), two pillars of the firm based innovative strategy.

[3] Though table 11 shows that the three effects are not statistically different.

Tab. 2 - Environmental innovations: correlated factors (EU)

	ECOMAT	ECOCO	ECOEN
	dF/dx	***dF/dx***	***dF/dx***
RMAC	0.067***	0.055***	0.092***
TURN08	1.22e-12	1.01e-12	1.73e-12
RD	0.079 ***	0.025***	0. 061***
FUNGMT	-0.006	0. 005	0. 008
FUNEU	0.005	0. 018	0. 029**
MKTINT	0.008	0. 008	0. 019
MKTEXT	0.008	-0. 003	0. 030
DUMMY_SINT	0. .035***	0. 057***	0.042***
DUMMY_SENTG	0.029**	0. 005**	0.013**
DUMMY_SMKT	0.040**	0. 034	0. 022
CO	0. 018**	0. 019**	0. 034***
Size dummy	yes	yes	yes
Country dummy	yes	yes	yes
Industry dummy	yes	yes	yes
N	17890	17768	17926

***significant at 1%; **significant at 5%; *significant at 10%.

Those results are more or less confirmed when looking at Germany (Table 6). In addition to the structural role played by dimensional, sector and country effects, ICT and information related factors appear significant. From an economic point of view, Germany shows up effects across EI that are more homogeneous for what regards ICT (RMAC), which is a possible signal of the higher EI diffusion of all EI in the German economy. The integration between ICT technologies and EI seems robust and relevant to explain the behavior of eco innovative firms.

Table 7 shows the importance of presenting disaggregated results when data availability allows it, where the Italian evidence is provided. Contrary to Germany but also to Portugal and to the Czech Republic, ICT does not play a major role in Italy to back EI adoption. This can be part of the deficiencies behind the Italian environmental performance (Marin and Mazzanti, 2013; Antonioli et al., 2013). On the other hand, R&D and above all local public funding appears to exert significant effects on EI. This is interesting given the strong regional features of Italian environmental policy (Costantini et al. 2013). Waste, material and energy efficiency policy package are largely composed of regional based instruments. Finally, the role of cooperation confirms to be a backbone of the Italian economic system, largely dependent upon the presence of SME that network and cluster in agglomerated areas, even for EI (See the coefficient of CO in Table 7). How this system would cope with the new challenges posed by the green economy in a globalized world is still under discussion. It seems from this evidence that the market forces of cooperation, in addition to firm based strategy (R&D and ICTs) and public funding are necessary steps along the greening of the Italian economy. Portugal resembles the Italian case besides the key ICT variable. It is significant but by a coefficient that testimonies a much lower integration with EI if compared to the German case. Finally for the only eastern EU country here, ICT is positively related to innovations aimed at reducing materials and energy in production (table 9). Again, ICT matters as well as R&D and information – cooperation variables in those cases. An industrial based country such as the Czech Republic seems to differ with respect to CO2. In that case, besides industry and size dummies only a few factors influence this more radical type of EI adoption.

In Table 10 we replicated the analysis at sectorial level, where it appears that only manufacturing and 'other services sectors' correlate with EI even if an effect for energy efficiency appears in the utility sector too. Marginal effects are slightly higher for energy efficiency. Overall, in a nutshell, the more ICT (software equipment) firms introduce, the higher is the likelihood they adopt EI of various kind. Country and sector effects matter as expected. Nevertheless, the main message is that ICT and EI are strongly correlated factors and that ICT and R&D are highly complementary for what concerns the adoption eco innovations. Firms that invest more in ICT and R&D are more likely to adopt EI, a signal of possible integration between various innovation strategies (table 12).

Tab. 3 - Environmental innovations: correlated factors (Germany)

	ECOMAT	ECOCO	ECOEN
	dF/dx	***dF/dx***	***dF/dx***
RMAC	0.137***	0.115***	0.165***
RD	0.074***	0.012	0.029
FUNLOC	-0.007	0.028	0.033
DUMMY_SENTG	0.010	-0.009	0.036
DUMMY_SMKT	0.060	0.054	0.004
DUMMY_SINT	0.111***	0.073***	0.107***
CO	-0.012	0.011	0.009
Size dummy	yes	yes	yes
Country dummy	yes	yes	yes
Industry dummy	yes	yes	yes
N	4759	4759	4759

***significant at 1%; **significant at 5%; *significant at 10%.

Tab. 4 - Environmental innovations: correlated factors (Italy)

	ECOMAT	ECOCO	ECOEN
	dF/dx	***dF/dx***	***dF/dx***
RMAC	-0.003	0.017	0.016
RD	0.043***	0.007	0.045**
FUNLOC	0.022*	0.025*	-0.0005
DUMMY_SENTG	0.012	-0.009	-0.0004 *
DUMMY_SMKT	-0.003	0. 0001	0.011
DUMMY_SINT	0.071***	0.057***	0. 057***
CO	0.018	0.028**	0. 017***
Size dummy	yes	yes	yes
Country dummy	yes	yes	yes
Industry dummy	yes	yes	yes
N	6546	6428	6583

***significant at 1%; **significant at 5%; *significant at 10%.

Tab. 5 - Portugal. Determinants of EI

	ECOMAT	ECOCO	ECOEN
	dF/dx	***dF/dx***	***dF/dx***
RMAC	0.079***	0.064***	0.094***
RD	0.086***	0.050**	0.092***
FUNLOC	0.047	0.153**	0.166**
DUMMY_SENTG	0.040	-0.024	0.025*
DUMMY_SMKT	0.039	0.011	0.068
DUMMY_SINT	0.069***	0.045**	0.101***
CO	0.050**	0.035*	0.060**
Size dummy	yes	yes	yes
Country dummy	yes	yes	yes
Industry dummy	yes	yes	yes
N	3760	3756	3759

***significant at 1%; **significant at 5%; *significant at 10%.

Tab. 6 - Czech Republic. Determinants of EI

	ECOMAT	ECOCO	ECOEN
	dF/dx	***dF/dx***	***dF/dx***
RMAC	0.093***	0.028	0.124***
RD	0.117**	-0.002	0.088***
FUNLOC	0.064	0.116*	0.154**
DUMMY_SENTG	0.045	0.031	0.011
DUMMY_SMKT	0.037	0.034	0.019
DUMMY_SINT	0.077***	0.052**	0.086***
CO	0.017	0.011	0.057**
Size dummy	yes	yes	yes
Country dummy	yes	yes	yes
Industry dummy	yes	yes	yes
N	2828	2828	2828

***significant at 1%; **significant at 5%; *significant at 10%.

Tab. 7 - Marginal effect of ICT on EI by sector

	ECOMAT	ECOCO	ECOEN
	dF/dx	***dF/dx***	***dF/dx***
MANIF	0.080***	0.072***	0. 106***
CONSTR	0.015	-0.025	-0.068
UTILITY	0. 046	0.046	0.139**
TRADE	0.051*	0.021	0.055*
OTHER	0.060***	0.047**	0.087***

***significant at 1%; **significant at 5%; *significant at 10%.

Tab. 8 - Test on differences among coefficients of rmac

Specification Compared	F-statistics (*p-value*)	Explanation
Ecomat & Ecoco	3.77 (0.001)	The coefficient of rmac for Ecomat is not statistically different from the coefficient of rmac for Ecoco
Ecomat & Ecoen	-1.28 (0.009)	The coefficient of rmac for Ecomat is not statistically different from the coefficient of rmac for Ecoen
Ecoco & Ecoen	-5.68 (0.000)	The coefficient of rmac for Ecoco is not statistically different from the coefficient of rmac for Ecoen

Null Hypothesis: difference between coefficient ≠ 0

Tab. 9 - Complementarity test on ICT and R&D adoption

ECOINNO							
ICT/R&D variables		ECOMAT		ECOCO		ECOEN	
		Wald Test	Signs of the linear combination (b1+b4)+(-b2-b3)	Wald Test	Signs of the linear combination (b1+b4)+(-b2-b3)	Wald Test	Signs of the linear combination (b1+b4)+(-b2-b3)
rmac	RD	18.38***	> 0	21.16***	> 0	25.83***	>0

***significant at 1%; **significant at 5%; *significant at 10%. The null is absence of complementarity. 'bi' are coefficients of the estimated regression associated to 'states of the world' 11, 10, 01, 00 (1 and 0 signals presence of absence of a defined input in the function that studies the complementarity. As example, 11 is the state for which both ICT and R&D are present.
(b1+b4)+(-b2-b3)≥0 is index of supermodularity
(b1+b4)+(-b2-b3)≤0 is index of submodularity

3.2 ICT, EI and complementarity in a Regional industrial system

We here restrict the focus to the survey on the Emilia Romagna region (around the size of Denmark) in the North of Italy to provide more refined and detailed evidence on ICT role in relation to the adoption of EI. We in fact exploit the much more detailed information that this specific survey on 555 firms delivers. We use this original source of information to infer new insights on the hypothesis that some sort of complementarity – between ICT and other techno-organizational factors – lies behind the adoption of EI, namely that EI is more present in firms that strategically and synergically match various innovations. We match various ICTs features (see table 13) with three key firm strategies (training, organizational innovations, technological innovation). Table 14 fully explains the set of variables we exploit in the econometric analysis. The Appendix shows up the Region map and the 'innovation diamond' of a firm that relates to the data we gathered from the survey (Figures 1 and 2).

Table A1 presents all 'states of the world' defined by the presence or absence of a defined element (with two elements we witness 4 states). Recalling what we highlighted in previous conceptual and empirical sections of the paper, the null hypothesis of complementarity is econometrically tested by calculating (b1+b4)+(-b2-b3)≥0 the index of supermodularity. If the sum of estimated coefficients leads to a reejction of the null, we might conclude that the two elements we focus on are complements with respect to the function we study (in this case an innovation type of function).

Tab. 10 – Descriptive Statistics (survey Emilia Romagna, n=555)

Descriptive statistics

	Whole sample			*Polluting sectors**		
	Mean	*StDev*	*Min/Max*	*Mean*	*StDev*	*Min/Max*
	(555 obs.)			*(141 obs.)*		
Dependent variables						
Energy/Material reduction per unit of product (**ENERGY**)	0.147	0.355	0/1	0.219	0.415	0/1
CO2 reduction (**CO2**)	0.115	0.319	0/1	0.163	0.370	0/1
Emissions reduction for soil, water and air (**EMISSIONS**)	0.140	0.347	0/1	0.198	0.400	0/1
Adoption of procedures like EMAS and ISO14001 (**EMASISO**)	0.144	0.351	0/1	0.170	0.377	0/1
ICT						
ICT_D	0.419	0.493	0/1	0.333	0.473	0/1
ICTSYSINTRO_D	0.289	0.284	0/1	0.235	0.273	0/1
ICT_PROD _D	0.659	0.474	0/1	0.652	0.477	0/1
ICT_SERVICE_D	0.636	0.481	0/1	0.609	0.489	0/1
INNOVATIONS						
ORG_D	0.482	0.500	0/1	0.482	0.501	0/1
TRAIN_D	0.803	0.397	0/1	0.851	0.357	0/1
TECH_D	0.488	0.500	0/1	0.439	0.498	0/1
Controls						
Size dummies	/	/	0/1	/	/	0/1
Sector dummies	/	/	0/1	/	/	0/1
INTERN_OPEN	0.021	0.066	0/0.83	0.019	0.057	0/0.33
R&D_INVEST_D	0.8	0.400	0/1	0.744	0.437	0/1

Note: _D means dummy variable *We define as the most polluting sectors the following ones: DE - Manufacture of pulp, paper and paper products; publishing and printing; DF - Manufacture of coke, refined petroleum products and nuclear fuel; DG - Manufacture of chemicals, chemical products and man-made fibres; DJ - Manufacture of basic metals and fabricated metal products. The two digit classification is in accordance with NACE Rev.1.

Tab. 14 – Covariates of the analysis

Dependent variables	
Energy/Material reduction per unit of product (**ENERGY**)	Dummy variable: 1 if innovations addressed to reduce use of materials and/or energy by output unit (included recycling) have been adopted; 0 otherwise
CO2 reduction (**CO2**)	Dummy variable: 1 if innovations addressed to reduce CO2 emissions have been adopted; 0 otherwise
Emissions reduction for soil, water and air (**EMISSIONS**)	Dummy variable: 1 if innovations addressed to reduce emissions for soil, water and air have been adopted; 0 otherwise
Adoption of procedures like EMAS and ISO14001 (**EMASISO**)	Dummy variable: 1 if procedures that structurally identify environmental performance have been adopted; 0 otherwise
ICT^	
ICT_D	Dummy variable: 1 if the value of the ICT composite index is above the mean; 0 otherwise. ICT composite index (values on the interval (0,1)) of innovation intensity in information and communication technologies sphere is constructed on the basis of the following specific variables: Index of ICT management systems implemented; Index of activities (production process, cooperation with client and suppliers, sell/buy activities) supported by ICT
ICTSYSINTRO_D	Dummy variable: 1 if the value Index of ICT management systems implemented is above the mean; 0 otherwise.
ICT_PROD_D	Dummy variable: 1 if the ICT systems implemented are addressed to manage the production process; 0 otherwise.
ICT_SERVICE_D	Dummy variable: 1 if the ICT systems implemented are addressed to manage cooperation with clients and suppliers (e.g. post selling services); 0 otherwise.
INNOVATIONS^	
ORG_D	Dummy variable: 1 if the value of the ICT composite index is above the mean; 0 otherwise. The composite index of innovation intensity in the organisational sphere (values on the interval (0,1)) is constructed on the basis of the following variables/indexes: Index of outsourcing activities; Index of collaboration activities to carry out organisational innovations; Index as the average number of production organisation practices; Index as the average number of labour organisation practices
TRAIN_D	The composite index of innovation intensity in training activities (values on the interval (0,1)) is constructed on the basis of the following variables/indexes: Index of training typologies; Percentage of permanent workers involved in training programs; Percentage of fixed-term workers involved in training programs; Index of training competencies covered by training programs (computing comp.; technical comp.; organisational/relational comp.; economic/legal comp.)
TECH_D	The composite index of innovation intensity in the technological sphere activities (values on the interval (0,1)) is constructed on the basis of the following variables/indexes: Index including innovation aspects belonging to the dimension of technological output; Index including innovation aspects belonging to the dimension of technological input
Controls	
Size dummies	4 size dummies according o the number of employees: 20-49 employees; 50-99 emp.; 100-249 emp.; more than 249 emp)
Sector dummies	8 secotrs dummies according to a two digit NACE Rev.1 classification: DA-Food; DB-DC Textile; DD-DH-DN-Wood, RubberPlastic and Other industries; DE-Paper; DF-DG-Coke and Chemicals; DI-NonMetallicMineralProducts; DJ-Metallurgy; DK-DL-DM-Machinery
INTERN_OPEN	Index capturing if the firm is an associated of a foreign one (values on the interval (0,1)): acquisition, joint venture, new firm from a foreign company, majority share in equity capital; minority share in equity capital
R&D_INVEST_D	1 if the firm invested in R&D; 0 otherwise

Note: _D means dummy variable ^When necessary the variables were dicotomised according to the following rule: 1 if the value of the variable is above the mean; 0 otherwise.

Table 15 shows that as often found, complementarity is not a low hanging fruit (Hall et al., 2012). Complementarity arises in 2 out of 48 cases: namely, regarding the joint effect of ICTSYNTRO-D and organizational change (ORG-D) on Energy efficiency and organizational environmental innovations (EMS/ISO). Firms that do 'invest' in specific types of ICT captured by ICTSYNTRO-D and organizational change are more likely to introduce EI. It is worth noting that CO2 and emissions are completely complementary free as far the role of the various investigate factors is concerned. This is a signal that EI is weakly integrated within the core set of firm's innovative actions. In addition, sectors that are more polluting and relatively more exposed to environmental policies (e.g. the EU ETS) are not placing EI and ICT related complementarity at the center of their strategies. In fact, table 16 presents a set of tests that do not rejects the null hypothesis of no-complementarity in all cases.

Overall, though the economies of scale and valuable integration effects that complementarity might generate when is placed at center of firm's strategies, it confirms to be a marginal factor when large numbers of firms are taken into account. Firms do tend to pursue innovative actions through non-integrated strategies. Even firms that are more exposed to policies do not use complementarity as a way to increase their efficiency and effectiveness. Though we cannot say that ICT and EI are uncorrelated factors (see section 3.1 and works as Cainelli et al., 2012), this relationship seems to be detached from the full techno-organizational change regime of a firm. We encourage further analysis through surveys that originally investigate other and more refined EI and ICT components.

Table 15 - Complementarities tests in a discrete setting. Linear restriction on states of the world coefficients from probit regressions

		ECOINNO							
ICT_D/INNO_D variables		ENERGY		CO2		EMISSIONS		EMASISO	
(Mean value used for dicotomisation)		Wald test§	Sign of the linear combination (b1+b4)+ (-b2-b3)	Wald test§	Sign of the linear combination (b1+b4)+ (-b2-b3)	Wald test§	Sign of the linear combination (b1+b4)+ (-b2-b3)	Wald test§	Sign of the linear combination (b1+b4)+ (-b2-b3)
ICT_D	ORG_D	1.19	≥ 0	0.00	≥ 0	2.70	≥ 0	2.91*	≥ 0
ICT_D	TRAIN_D	0.02	≥ 0	0.03	≤ 0	0.36	≤ 0	0.00	≤ 0
ICT_D	TECHNO_D	0.56	≥ 0	1.17	≤ 0	0.96	≥ 0	0.96	≥ 0
ICTSYSINTRO_D	ORG_D	4.29**	≥ 0	0.88	≥ 0	1.93	≥ 0	3.97**	≥ 0
ICTSYSINTRO_D	TRAIN_D	0.23	≤ 0	0.47	≤ 0	0.41	≤ 0	0.44	≥ 0
ICTSYSINTRO_D	TECHNO_D	0.44	≥ 0	0.31	≥ 0	0.07	≥ 0	0.03	≥ 0
ICT_PROD _D	ORG _D	0.15	≤ 0	0.04	≥ 0	0.03	≥ 0	0.00	≤ 0
ICT_PROD _D	TRAIN _D	n.f.	n.f.	0.68	≥ 0	0.57	≤ 0	0.10	≥ 0
ICT_PROD _D	TECHNO _D	0.09	≤ 0	0.07	≤ 0	0.02	≥ 0	2.08	≤ 0
ICT_SERVICE_D	ORG _D	0.01	≥ 0	0.00	≥ 0	0.01	≤ 0	0.00	≤ 0
ICT_ SERVICE_D	TRAIN _D	0.00	≥ 0	0.22	≥ 0	0.01	≥ 0	0.07	≥ 0
ICT_ SERVICE_D	TECHNO _D	1.97	≥ 0	0.87	≥ 0	0.07	≥ 0	1.30	≥ 0

§ 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

Significanace signals that we may reject the null of absence of complementarity

$(b1+b4)+(-b2-b3)\geq 0$ is index of supermodularity

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

Note: Tests conducted on marginal effects provide the same results (not reported for space constraint but available from the authors upon request); n.f. means that the Wald test is not feasible because specific states of the world are dropped, since they predict failure (0) or success (1) of the dependent variable perfectly.

Table 16 - Complementarities tests in a discrete setting. Linear restriction on states of the world coefficients from probit regressions. Polluting sectors: Metallurgy, Paper, Chemical-Rubber

		ECOINNO							
ICT_D/INNO_D variables		ENERGY		CO2		EMISSIONS		EMASISO	
(Mean value used for dicotomisation)		Wald test*	Sign of the linear combination (b1+b4)+ (-b2-b3)	Wald test*	Sign of the linear combination (b1+b4)+ (-b2-b3)	Wald test*	Sign of the linear combination (b1+b4)+ (-b2-b3)	Wald test*	Sign of the linear combination (b1+b4)+ (-b2-b3)
ICT_D	ORG_D	1.14	≥ 0	1.53	≤ 0	1.20	≥ 0	0.03	≥ 0
ICT_D	TRAIN_D	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.
ICT_D	TECHNO_D	0.52	≥ 0	0.51	≥ 0	0.06	≥ 0	0.81	≥ 0
ICTSYSINTRO_D	ORG_D	0.19	≥ 0	0.40	≤ 0	0.11	≥ 0	0.90	≥ 0
ICTSYSINTRO_D	TRAIN_D	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.
ICTSYSINTRO_D	TECHNO_D	0.00	≤ 0	0.34	≤ 0	0.08	≤ 0	0.03	≤ 0
ICT_PROD _D	ORG D	0.05	≤ 0	0.01	≥ 0	0.78	≥ 0	0.98	≤ 0
ICT_PROD _D	TRAIN _D	n.f.	n.f.	0.82	≥ 0	n.f.	n.f.	n.f.	n.f.
ICT_PROD _D	TECHNO_D	0.21	≤ 0	0.16	≤ 0	0.00	≤ 0	4.54	≤ 0
ICT_SERVICE_D	ORG_D	1.42	≥ 0	1.02	≥ 0	1.08	≥ 0	0.09	≥ 0
ICT_ SERVICE_D	TRAIN _D	n.f.	n.f.	0.13	≥ 0	n.f.	n.f.	n.f.	n.f.
ICT_ SERVICE_D	TECHNO_D	0.21	≥ 0	0.11	≤ 0	2.21	≤ 0	0.28	≥ 0

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=141

Significanace signals that we may reject the null of absence of complementarity

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

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

Note: Tests conducted on marginal effects provide the same results (not reported for space constraint but available from the authors upon request); n.f. means that the Wald test is not feasible because specific states of the world are dropped, since they predict failure (0) or success (1) of the dependent variable perfectly.

4. Conclusions

The paper enriches the literature and the evidence around eco innovation adoption by firms by introducing the role of ICT as a main eventual correlated factor. ICTs are a prominent technological pillar to achieve a dematerialisation and decarbonisation of the economy. Their effective role within firms green strategies is nevertheless somewhat overlooked often due to paucity of data. In addition, we use the lens of complementarity theory to assess whether the synergies between different innovative firm strategies are eventually behind the adoption of EIs, namely whether EIs are adopted more as an isolated factor or as an element of a more integrated strategy that pursue sustainability and competitive by bundling together different innovations. In order to deliver original empirical evidence, we exploit two pretty original sources: first, the CIS 2006-2008 that presents information – among other firm's innovative strategies - on both EIs and ICT adoption; second, a rich survey that covers 555 firms in a Region of Northern Italy and contains the same CIS-like data on EIs and additionally more detailed information on various elements of ICT strategies within a firm.

We find that ICT adoption is robustly and positively correlated to EI in the EU. In addition, complementarity is characterizing the relationship between ICT and other innovation processes as a force behind EI, but it is not to be taken for granted. In fact, it appears a robust empirical fact with regard to general innovation capacity (R&D and ICT), though when we narrow down the focus to specific techno-organizational innovations, complementarity with ICT is rare as a pillar to green firm's strategies. Further research might focus on the complementarity between ICT and EI as an 'asset' promoting higher economic and environmental performances. Micro and meso level data might be used for that aim.

References

Antonioli D. Mancinelli S. Mazzanti M. (2013), Are Environmental Innovations embedded within organizational change? *Research Policy*, forth.

Berkhout F., Hertin J. (2004), "De-materialising and re-materialising: digital technologies and the environment", *Futures*, 36, 903-920.

Böhringer C., Moslener, U. Oberndorfer U. Ziegler A. (2008), Clean and Productive? Evidence from the German Manufacturing Industry, ZEW Discussion Paper No. 08-091, Mannheim.

Borghesi, S., Cainelli, G., Mazzanti, M., (2012), Brown sunsets and green dawns in the industrial sector, Nota di lavoro n.3, FEEM, Milan.

Brunnermeier, S.B., Cohen, M.A., (2003), Determinants of environmental innovation in US manufacturing industries, Journal of Environmental Economics and Management 45, 278–293.

Cainelli G. Mazzanti M. Montresor S. (2012), Environmental innovations, internationalisation and local factors, *Industry and Innovation*, November.

Cassiman, B. and Veugelers R. (2002), R&D cooperation and spillovers: Some empirical evidence from Belgium. The American Economic Review 92 (4), 1169–1184.

Cecere, G. Corrocher N. Gossart C. Ozman M. (2012), Patterns of Innovation in green ICT, a patent based analysis, SSRN paper, July.

Cleff, T. and Rennings, K., (1999), Determinants of Environmental Product and Process Innovation, *European Environment* 9 (5), 191-201.

Costantini, V. Mazzanti, M. (2012), On the green and innovative side of trade competitiveness? The impact of environmental policies and innovation on EU exports, Research Policy, Elsevier, vol. 41(1), pages 132-153.

Costantini, V. Mazzanti, M. Montini A. (2013), Environmental performance, Innovation and Regional spillovers, Ecological Economics, forth.

De Marchi, V., (2012), Environmental Innovation and R&D cooperation: Empirical evidence from Spanish manufacturing firms, Research Policy, vol. 41, issue 3, p. 614- 623

Del Rio Gonzalez, P. (2009), The empirical analysis of the determinants for environmental technological change: A research agenda, Ecological Economics, Vol. 68, 861-878.

Frondel, M., Horbach, J., Rennings, K. (2004), End-of-Pipe or Cleaner Production? An Empirical Comparison of Environmental Innovation Decisions Across OECD Countries, Business Strategy and the Environment, ZEW Discussion Paper No. 04-82

Gilli M. Mazzanti M. Nicolli F. (2013), Sustainability and Competitiveness in Evolutionary Perspectives. Environmental Innovations, Structural Change and Economic Dynamics in the EU, quaderno DEM n.4 University of Ferrara (forth J of Socio Economics).

Hall B. Lotti F. Mairesse J. (2012), Evidence on the Impact of R&D and ICT Investment on Innovation and Productivity in Italian Firms', Economics of Innovation and New Technology (previously NBER WP. 18053)

Horbach, J. (2006), Determinants of Environmental Innovation – New Evidence from German Panel Data Sources, Working Papers 2006.13, Fondazione Eni Enrico Mattei

Horbach, J. & Rennings K. (2012), Environmental innovation and employment dynamics in different technology fields: An analysis based on the German community innovation survey 2009, ZEW

Discussion Papers 12-006, ZEW

Horbach, J. and Oltra, V. (2010), Determinants and Specificities of Eco-innovations – An Econometric Analysis for the French and German Industry based on the Community Innovation Survey, paper presented at the world conference of environmental economists, Montreal, June-July 2010

Horbach, J. (2008), Determinants of Environmental Innovation – New Evidence from German Panel Data Sources, Research Policy, Vol. 37, 163-173.

Horbach, J., Rammer, C., & Rennings, K. (2012),.Determinants of eco-innovations by type of environmental impact—The role of regulatory push/pull, technology push and market pull. Ecological Economics, 78: 112-122.

Jaffe, A., Palmer, K. (1997), Environmental regulation and innovation: a panel study,The Review of Economics and Statistics, 610–619.

Jaffe, A.B., Newell, R.G., Stavins, R.N., (2002). Environmental Policy and Technological Change, Environmental and Resource Economics 22, 41–69.

James, P., and Fussler, C. (1997), Driving Eco-Innovation- A breakthrough Discipline for Innovation and Sustainability. London: Pitman Publishing.

Johnstone, N., Haščič, I., Poirier, J., Hemar, M., Michel, C. (2012), Environmental policy stringency and technological innovation: evidence from survey data and patent counts, Applied Economics, 44:17, 2157-2170

Kemp, R. (2010), Eco-Innovation: definition, measurement and open research issues, Economia Politica, XXVII(3), 397-420.

Mancinelli S. Mazzanti M., 2009, Innovation, networking activities and complementarity Empirical evidence on SME performances for a local economic system in Northern Italy, *Annals of Regional sciences*, vol.43, n.3, 567-97.

Marin G., Mazzanti M. (2013), The evolution of environmental and labour productivity dynamics, Journal of Evolutionary Economics, vol. 23, n.2, 357-399.

Mazzanti M., Zoboli R. (2009), Embedding environmental innovations in local production systems: SME strategies, networking and industrial relations, International Review of Applied Economics, vol.23, n.2, 169-195

Mazzanti M. Zoboli R., 2008, Complementarity, firm strategies and environmental innovations, *Environmental sciences*, vol.5, n.1, pp.17-40

Milgrom P, Roberts J (1995) Complementarities and fit strategy, structure, and organizational change in manufacturing. *Journal of Accounting and Economics*, 19(2-3): 179-208

Montresor, S. and Vittucci Marzetti, G. (2011), "The deindustrialisation/tertiarisation hypothesis reconsidered: a subsystem application to the OECD", *Cambridge Journal of Economics*, Vol. 35, n.2: 401–421.

Nogareda, J. S. and Ziegler, A., (2009), Green Management and Green Technology – Exploring the Causal Relationship, ZEW Discussion Paper No. 2006-040 (2009 Research Policy)

OECD (2009), *Measuring the relationship between ICT and the environment*, OECD n.162 Digital economy paper, OECD.

OECD (2010) *Greener and Smarter – ICTs, the Environment and Climate Change,* OECD, September 2010

Rehfeld, K.-M., Rennings, K., Ziegler, A., 2007. Integrated product policy and environmental product innovations: An empirical analysis. Ecological Economics 61, 91–100.

Rennings, K. Rexhauser S., (2010), snowball effects and time lags of regulation on innovation – cumulative impacts of environmental policy phases on companies' eco-innovative activities, paper presented at the world congress of environmental and resource economists, Montreal, June July 2010

Rennings, K., Ziegler, A., Ankele, K., Hoffmann, E., Nill, J., (2006). The influence of different characteristics of the EU environmental management and auditing scheme on technical environmental innovations and economic performance. Ecological Economics 57, 45–59.

Wagner, M., (2007), On the relationship between environmental management, environmental innovation and patenting: Evidence from German manufacturing firms, Research Policy, 36(10), 1587-1602.

Veugelers R. (2012), Which policy instruments to induce clean innovating? *Research Policy*, *41, 1770-1778*

Ziegler, A., Rennings, K., (2004). Determinants of environmental innovations in Germany: do organizational measures matter? A Discrete Choice Analysis at the Firm Level. ZEW Discussion Paper, vol. 04-30.

Appendix

Table A1 - State of the world distribution

		States of the world (555 obs.) whole sample %				States of the world (141 obs.) polluting sectors %			
		(1,1)	(1,0)	(0,1)	(0,0)	(1,1)	(1,0)	(0,1)	(0,0)
ICT_D	ORG_D	27.75	14.23	20.54	37.48	22.70	10.64	25.53	41.13
ICTSYSINTRO_D	ORG_D	26.31	17.84	21.98	33.87	17.02	14.18	31.21	37.59
ICT_PROD _D	ORG _D	36.40	29.55	11.89	22.16	34.75	30.50	13.48	21.28
ICT_SERVICE_D	ORG _D	34.41	29.19	13.87	22.52	31.21	29.79	17.02	21.99
ICT_D	TRAIN_D	35.68	6.31	44.68	13.33	27.66	5.67	57.45	9.22
ICTSYSINTRO_D	TRAIN_D	36.22	7.93	44.14	11.71	25.53	5.67	59.57	9.22
ICT_PROD _D	TRAIN_D	56.04	9.91	24.32	9.73	57.45	7.80	27.66	7.09
ICT_SERVICE_D	TRAIN_D	52.07	11.53	28.29	8.11	53.19	7.80	31.91	7.09
ICT_D	TECH_D	28.47	13.51	20.36	37.66	20.57	12.77	23.40	43.26
ICTSYSINTRO_D	TECH_D	27.39	16.76	21.44	34.41	18.44	12.77	25.53	43.26
ICT_PROD _D	TECH_D	36.58	29.37	12.25	21.80	31.21	34.04	12.77	21.99
ICT_SERVICE_D	TECH_D	35.32	28.29	13.51	22.88	30.50	30.50	13.48	25.53

Figure A1 – The Emilia Romagna Region (5 millions inhabitants, GDP per capita 33,000€, 18% italian industry GDP)

Figure A2 - The Innovation diamond