UNIVERSITÀ DEGLI STUDI DI FERRARA
DIPARTIMENTO DI ECONOMIA E ISTITUZIONI TERRITORIO
Via Voltapaletto, 11 – 44100 Ferrara

Quaderno n. 15/2011

October 2011

Are Environmental Innovations Embedded within High-Performance Organizational Changes?

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Davide Antonioli*, Susanna Mancinelli* and Massimiliano Mazzanti*

Abstract

Many scholars have highlighted the role of high performance work practices (HPWP) and Human Resource Management (HRM) as contents of organizational change that integrate with green business strategies, mainly in the realm of the 'Porter paradigm of change' and competitive advantage. We investigate whether manufacturing firms, in light of the challenges that the path to a 'Green economy' poses, have given heavier weight in most recent times to internal sources of environmental innovation (EI) that refer to structural mechanisms of organizational change. More specifically, we analyse how the complementarity between different performance oriented strategies such as training and organizational innovations of labor and production can (jointly) foster the adoption of relatively more radical innovations, as environmental ones are. We use an original dataset on 555 Italian industrial firms on EI and high performance work practices, coherent with the last CIS5 survey, to analyse whether various, more or less radical, forms of environmental innovations are correlated to complementarity investments in HPWP/HRM. Empirical evidence shows that the strict complementarity assumption is not valid as a general rule for the HPWP/HRM strategies we analyse. We indeed find that trade offs (substitutability) is present when training competencies and organizational change in production are investigated. Weaknesses in organizational change processes are then highlighted for the sake of management restructuring. Sector specificity and market conditions eventually matter: the only case where we do find strict complementarities in organizational change is for CO_2 abatement, a relatively more radical type of EI, but when we restrict the sample to more polluting (and regulated) firms. This evidence is coherent with the Porter hypothesis: complementarity related adoption of EI is an element of organizational change in firms that are subject to more stringent regulations. The fact that strict complementarity is not a diffused factor behind the adoption of all environmental innovations does not come indeed at a surprise. At this stage of development of green strategies, the share of eco-firms is still limited even in advanced countries that are seeking for new competitiveness tools. Market Leaders do find innovations sources mainly 'outside' the boundaries instead of reshaping organizations along complementary green lines. The integration of EIs with the internal capabilities and firm's own assets is far from being reached even in advanced and competitive industrial settings.

Keywords: environmental innovations, complementarity, HRM, HPWP, training, innovation survey, manufacturing firms, Porter hypothesis

JEL: L6; M53; O3; Q55

* University of Ferrara, Faculty of Economics, Department of Economics Institutions Territory, Via voltapaletto 11, 44100, Ferrara. Contacts: ntndvd@unife.it; mncsnn@unife.it; mzzmsm@unife.it.

1. The background: Organizational changes, Human resource management and complementarity behind (environmental) innovation

With the diffusion of evolutionary theorising and heterodox perspectives in the analysis of the firm (Teece, 1996; Coriat and Dosi, 2002; Foss, 2005), increasing attention has been devoted to the organisational structure of the firm itself (Osterman, 2000; Lynch, 2007) and to the impact that changes in organisational dimensions may have both on innovation activities and on the economic performance of the firm[1]. It is worth spending some words on the definition of organisational changes, at least as we intend them here. The reference literature concerns the studies adopting the terminology of High Performance Workplace Practices (HPWP)[2], to define a set of organisational 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 organisation (e.g autonomous or semi-autonomous teams, quality circles) and labour organisation (e.g. job rotation, multitasking, increased workers responsibility), we can number the supporting Human Resource Management (HRM) practices, which are also referable to the training activities sphere: the human capital of the employees becomes a fundamental resource since "innovating organization benefits from a strong skill-base" (Leiponen, 2005, p.304), which is able to sustain and direct the absorptive capacity. It becomes clear the importance of training activities[3] that help generating and accumulating skills and competences, 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 (Van den Bergh and Stagl, 2003), influence each other and impact on firm's innovative performance. Indeed, when a firm passes through organisational changes, such as the introduction of HPWP, than the employees could be asked to learn how to manage and how to behave in a new organisational environment. Since employees are managed through the set of HRM practices, these latter become fundamental in shaping and developing specific capabilities, inducing the accumulation of new knowledge, the reformulation of the old one and the diffusion of both. It is not by chance that HPWP and HRM practices may be thought as different dimensions of a so called High Performance Work System (HPWS) (EU, 2000; Osterman, 2000; 2006). However, given the nature of our aim and analysis we here pay less attention to the systemic characteristic a 'reorganised' workplace may have, and more to the single practices, so we do not adopt a systemic perspective talking of HPWS but we prefer to consider the organisational practices in their distinctiveness as HPWP and HRM.

Hence, sticking on the relation between the pair HPWP/HRM and innovations, which is of main interest for the present work, we may argue that the organisational structure of the firm acts as an important enabler for the techno-organisational innovation performance in a broad and extensive meaning (Jensen et al., 2007; Arundel et al, 2007): poor or obsolete production and labour organisations may lock in the firm on a sterile and obsolete technological path or on low value added productions. Reconfiguring the organisational system in a way that increases the workforce involvement and skill base, through the implementation of complementary HPWP/HRM practices, may be functional to the creation of an environment that smoothly absorbs and exploits also radical innovations.

From the studies on HPWP and HRM role in fostering firm innovations and economic performances a specific and fully relevant literature on complementarity has originated. Since the

[1]For the relation between organisational changes and firm economic performance see among others: Black and Lynch, 2001; Caroli and Van Reenen 2001; Janod and Saint-Martin, 2004; Huselid, 1995; Huselid and Becker, 1996; Cappelli and Neumark, 2001; Ichniowski, Shaw and Prennushi 1997; Ichniowski, 1990; Zwick, 2004.

[2]A surge of names has been assigned to the 'new organisational practices' according to the practices selected and to the perspective adopted in the different studies: e.g. High Performance Work Systems (Ramsay, Scholarios and Harley, 2000; Osterman, 2006); High Involvement Management (Bryson, Forth and Kirby, 2005); High Commitment Management (Dorenbosch, Van Engen and Verhagen, 2005); Bryson, Gomez and Kretschmer, 2005).

[3]For empirical evidence on the relations between training and firm economic performance see among others: Zwick (2005) and Conti (2005).

seminal work by Mohnen and Roller (2005) a niche literature has developed (Mancinelli and Mazzanti (2009), Mairesse and Mohnen (2010)). The studies have primarily focused on EU countries, looking at complementarity with respect to both innovation (drivers and brakes) and economic performances, with evidence on various innovation spheres (ICT, technological product and process innovations). Though complementarity is possibly assessed even at the level of correlation between 'adoptions' (e.g. process and product, eco and ICT innovations) we here mainly refer to complementarity assessments that put a lens on the input side. This is a theoretical framework that is consistent and refer to the Milgrom and Roberts (1990, 1995) definition of super modularity between innovation inputs (generally, firm's performances). From an empirical point of view, complementarity is a way to strengthen appropriability conditions, and has been increasingly analysed over the years (Mairesse and Mohnen, 2010, who extensively touch upon the complementarity issue in their survey). According to the definition by Ennen and Richter (2009) meta analysis on complementarity studies (up to 2008), we are here more interested in examinations of two-three way relationships among individual elements of firm's organisational change, alternative to investigations of 'entire' systems of complementarity. They conclude that 'complementarities are system specific phenomena. Studies of relationships among individual elements of factors can offer valuable insights, but the failure of such a study to confirm complementarity effects where it had been expected them may mean that the full range of factors at work and their relationships have not yet been fully understood' (Ennen and Richter, 2009, p.3).

Examples of studies that focus on complementarity assessments and try to extend the methodological scope and thematic coverage are also the seminal work by Galia and Legros (2004), Bocquet et al. (2007), Schmiedeberg (2008) and Gomez and Vargas (2009). The first two works, with the latter that originally focus on ICT various strategies, are the only ones adopting the super modularity framework. New innovations and themes have thus been added on top of the classical analysis on process and product, incremental and radical, technological innovations[4].

Moving to the core of the issue, we note that Environmental Innovations (EI) has been touched by complementarity assessments (Mazzanti and Zoboli, 2008) with emphasis on links between internal and external sources such as cooperation and R&D. This 'innovation inputs' pair (R&D and cooperation) is probably the most analysed in recent years.

What it really lacks in our eyes in the current research agenda is an analysis of the potential relationship between HRM/HPWP and EIs, which is by the way fully pointed out as a core issue by the scholars that study the development of the well known Porter hypothesis (that induced environmental innovation is driven by regulations and CSR firm behaviour and lead to higher competitiveness; see Ambec and Barla, 2006; Ambec and Lanoie, 2008; Lanoie, 2011; Ambec et al., 2010; Costantini and Mazzanti, 2011) as a key unexplored factor of change. Some recent studies tried to shed light on this unexplored issue in the EI related literature. Among others, we can only quote Cole (2008) who assess the role of foreign derived training on a sample of african firm's environmental performance (finding that foreign training of a firm's decision maker, not foreign ownership per se, does reduce fuel use), and surely Bloom et al. (2010), who survey UK manufacturing firms to assess whether energy efficiency performances are impacted by various forms of HPWP. They find mixed evidence. More general proxies of human capital management (defined 'new management practices' within the realm of HPWP, see Huselid and Becker, 1996) do not have an impact, while some others seem to decrease energy use.[5]

[4]In addition to the studies looking to single two-three elements over which testing complementary relations we also mention the works by Laursen (2002), Michie and Sheehan (2003) and Laursen and Foss (2003), which check for complementarities among a wide range of HRM practices defining HRM systems of practices through the implementation of a multivariate analysis (e.g. principal component analysis) to define bundles of practices or grouping the practices according to predetermined criteria related to the firms organizational structure.

[5]It is worth reporting what stated by Bloom et al. (2010, p. 567): 'is that almost all management practices are negatively correlated with energy intensity. This supports the idea that the subset of practices which we focus on in our survey are all highly complementary leading to better managed, more energy efficient firms. Interestingly though, some practices appear particularly strongly linked with lower energy intensity – the use and analysis of key performance indicators of

We are not aware of studies that investigate the role of HPWP/HRM couple in the specific theme of EI adoption (see the seminal work by Rennings, 2000), though we observe that a recent EU report has emphasised the role of human capital and organisational capital among the basket of EI drivers (Technopolis, 2008), which is instead neglected in more standard assessment of EI (OECD, 2008)[6]. There are papers which find a positively effect of training (es. In terms of coverage) on EI performances (Horbach, 2008; Horbach et al., 2011; Cainelli et al., 2011). The lack of integration between environmental innovation/economics studies and the stream of organisational change research is clear. A recent paper that is probably closer to our attempt to merge environmental and HPWP/HRM perspectives is Pekovic (2011)[7], which nevertheless does not touch upon complementarity assessments.

A full integration of EI in firms innovation strategies is possible and needed to turn EU from 'green washing' or 'ancillary' strategies into a key issue in firms redefinition of competitive advantages. The integration of EI into firms (complementary) investments is also a way for medium small sized firms, that rarely patent innovations, to increase EI adoption rates and their effectiveness. Diffusion and win win scenarios is also stimulated by integrated EI investments, given the increasing returns to scale that characterise complementarity forms of investments. 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; EIO, 2011).

Thus, the main objective of the paper is to investigate environmental innovations driving forces associated to human resource management (HRM) and organisational changes (HPWP), assessing their impact through the lens of complementarity theory that points to the hypothesis that 'the whole is more than the sum of its parts'. This is especially relevant to be studied for HRM/HPWP that often show and possess embedded and interlinked structures, and in the case of somewhat 'radical' innovations such as those of environmental nature, CO2 abatement in primis, which makes necessary a 'behind the curtain' full restructuring of the firm organisation.

The main research question of the paper is whether manufacturing firms, belonging to heavily environmental regulated sectors in many fields such as CO2, emissions, waste (e.g. EU emission trading 2003 Directive, IPPC 2008 Directive on emissions abatement and environmental technology and its 2010 revision, EU waste Packaging Directives of 1994 and 2003, etc..), have embedded the adoption of EI[8] in the broader realm of organizational change where complementarity strategies

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production (Review of Performance, Performance Dialogue, Consequence Management) and people management (Rewarding high performance, Removing poor performers, Promoting High Performers, Attracting Human Capital). Hence, it seems that the mere existence of performance measurement (Performance Tracking) or of lean manufacturing practices are not sufficient to generate a significant negative relation with energy intensity'. They nevertheless intuitively give emphasis to complementarity, given that they do not report specific tests on any sort of complementarity definition.

[6] We note that the emphasis on 'complementarity' holds attention to means of appropriability of innovation rents that are different from those of patenting (to which OECD mostly devotes attention). In industrial systems such as the Italian one, where small / medium sized firms are prevalent, intangible ways to capture rents are more relevant (Brioschi et al., 2002). Complementarity – as asset specificity - is one of them.

[7] The study exploits an employee-employer dataset on French firms covering 2003-2006. The main tested hypotheses are that the adoption of environmental standards is associated with training, and then training (composite indicator of various practices), in a two steps conceptual model, impacts firm productivity. Environmental innovations are assumed to enhance high commitment HRM practices, encourage employee involvement and reshape work organization. We underline that such new challenges involve many changes of many inputs: complementarity but also trade offs can result especially in the short run. Results show that environmental standards are correlated with increases in training intensity. Greener firms show higher labor oriented strategies, and this is finally beneficial for firm-specific performance.

[8] For discussions on EI we refer to Mazzanti and Zoboli (2009a), Kemp (2010) and Kemp and Pontoglio (2011). In addition, we note that Kemp (2000) addresses EI policy impacts through a 'modulation approach', where within an evolutionary framework, the effect on EI of environmental policy is extensively defined in its scope and aims: the focus of environmental technology policy is on all technologies, EI includes organisational processes, it effectively stems from synergies between instruments, co-evolution between policy and innovation realms is relevant, society involvement in innovation processes and policy design is needed, policy making is forward looking and adaptive, aimed

drive the value of the change. The conceptual framework is that of the Porter idea of firm competitive advantages that resides in the firm value chain. HRM is a key pillar and 'Strategy is manifested in the way activities are *configured* and *linked together'* (Porter, 2010).
We investigate the issue by using new and original data that cover 555 Italian firms belonging to environmentally regulated manufacturing sectors, over 2006-2008, the same time span of the last CIS. We thus assure great comparability. EIs questions could in fact replicate those implemented in the last CIS for the first time, since they derived from the outputs and hints of the EU MEI project which also informed the EU CIS (CIS based studies are surveyed by Mairesse and Mohnen, 2010, that highlight how 'questions regarding environmental innovations have recently made their appearance').
The paper is structured as follows. Section 2 presents the theoretical framework in the attempt to shape it for this and future analysis of the same nature, and sets out the main research questions. Section 3 presents the survey and the original dataset. Section 4 shows the econometric analyses and complementarity tests. Section 5 concludes.

2. Environmental innovation and complementarity among HPWP/HRM practices: concepts and methods

Recently, eminent scholars that have contributed to the environmental Porter Hypothesis (PH) debate (Ambec et al., 2010; Lanoie, 2011) in a reassessment of the hypothesis 20 years from its birth have emphasised the role of competencies and training to achieve substantial adoption of radical forms of change as environmental innovations, at least a great part of those radical changes (carbon reductions, closed material loops, recycling, etc..) need a full restructuring of the firm organization, both internal features and external boundaries.
The PH says in its weak/narrow and strong perspectives (Jaffe and Palmer, 1997; Jaffe et al. 1995; Wagner, 2008, 2007, 2006) that environmental regulation can stimulate innovations that offset the costs of pursuing that standards and that enhance firms productivity (Porter, 1995; Porter and van der Linde, 1995, Costantini and Mazzanti, 2011; Mazzanti and Zoboli, 2009b). This 'offset effort' requires an often dramatic change in the way the firm approaches the management of its resources. What is of interest here is that in both cases of innovation offsets due whether to product or to process offsets, the basis upon which Porter relies is that of a systemic view of the firm. What we do in the present work is to merge this relevant approach with the approach that is at the basis of the concept of complementarities. Complementarities among firms' resources are at the heart of a systemic view of the firm. Radical innovation changes require not only the adoption of innovation drivers (R&D, networking, HPWP, etc..), but the synergic use of resources, which is in itself an intangible asset for achieving increasing returns to scale and thus higher competitiveness. The complementarity framework should be nevertheless clearly defined, given that as for 'sustainability', the term is often used without a clear theoretical reference.
Since the pioneering works of Milgrom and Roberts (1990, 1995), what economists investigate through complementarities is the extent to which different elements of strategy, structure and managerial processes in a firm fit one another and show coherence among them. We agree with Ballot et al (2011, p.2): "the complementarities perspective is not itself a theory of organizational design, but rather an approach to help researchers to understand relational phenomena and how the relationships between parts of system create more value than individual elements of the system". To the point that if only one of the complementary elements is undertaken by the firm and no attention

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at dynamic more than static efficiency, efficiency and effectiveness are joint aims. The approach is that 'the capabilities, interests, interdependencies and interactions of social actors around an environmental problem are relevant, instead of the environmental problem itself and how this problem may be solved through the (flexible) and synergic use of economic instruments.

is devoted to the others, firm's performance may even worsen. Since the other seminal applied work by Mohnen and Roller (2005), increasing attention has been devoted by the economic literature to testing empirical evidence for complementarities in innovation policy (both among drivers and/or boundaries). For what concerns environmental innovation issues the emphasis on complementarity has been put on links between internal and external sources such as cooperation and R&D (Mazzanti and Zoboli, 2008), where such links could refer both to complementarities and to positive spillover, but not HRM and HPWP elements.

What it really lacks is therefore an analysis of the relationship between different forms of environmental innovations (such as emission abatement, carbon reductions, EMS/ISO adoption) and HRM/HPWP strategies. The relevant role of HRM has already been highlighted, following the Porter paradigm, in the increasing need to adopt integrated green strategies and not only "end of pipe" technology (Lanoie, 2011). The systemic approach already adopted in the economic literature on innovation[9] must necessarily be extended also to environmental innovation, and good tools to deal with this kind of approach are those related to the study of complementarities.

It is worth noting that our aim is to concentrate our analysis on the relationships of complementarity, and not on positive spillovers[10].

Since HRM/HPWP and innovation practices are typically investigated by means of discrete settings (e.g. adopting or not, adopting at intensity higher than the average, etc..), we study complementarity between these forms of actions, that could generate as a result larger probability of adopting EI in such firms, through the properties of supermodular functions. This technical approach has the benefit to let focusing 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[11].

Following Topkis (1995, 1998), Milgrom, Roberts (1990, 1995), Milgrom, Shannon (1994), we say that a set of variables $x \in X \subseteq R^n$ is complementary if a real-valued function $F(x)$ on a *sublattice* $X \subseteq R^n$ is supermodular in its arguments.

A real-valued function F on a *sublattice*[12] X is defined *supermodular* in its arguments, if and only if:

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

Or, written in a different way:

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

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'): having *more* of one variable *increases* the returns to

[9] See, among others, Galia and Legros (2004).

[10] "Note that complementarity is conceptually different from a positive spillover. A positive spillover occurs when the overall benefit from some activity (rather than the returns to increasing the activity) is increasing in the level of the other activity" (Roberts, 2006, p. 11).

[11] "The implications of supermodularity do not depend on the usual kinds of specialized assumptions […]. For example, we do not need any divisibility or concavity assumptions, so increasing returns are easily encompassed" (Milgrom and Roberts, 1995, p. 184)

[12] Going into details, we define a *sublattice* $(X,\geq)$ a set X, with a partial order $\geq$, such that for any $x', x'' \in X$ the set X also contains a smallest element under the order that is larger than both x' and x'' ($x' \vee x''$) and a largest element under the order that is smaller than both x' and x'' ($x' \wedge x''$). In the n-dimensional Euclidean space, R^n, $x' \vee x''$ and $x' \wedge x''$, are:
$x' \vee x'' = \left(\max\{x'_1, x''_1\}, \ldots, \max\{x'_n, x''_n\}\right)$, and $x' \wedge x'' = \left(\min\{x'_1, x''_1\}, \ldots, \min\{x'_n, x''_n\}\right)$.

having *more* of the other[13]. Supermodularity gives an analytical structure to the systemic idea that the whole is more than the sum of its parts (Milgrom and Roberts, 1995).
In our specific case we consider firm's EI function (EI_j) as the firm's objective function and we focus on just two[14] of the many HRM practices that can affect firm's EI function, h' and h'':

(3) $$EI_j = EI_j(h', h'', \theta_j) \quad \forall j.$$

The problem of firm j is to choose a set of HRM practices, $(h', h'') \in H \subseteq R^2$, which maximizes its EI function. From the supermodularity properties we can assert that whenever practices are complementary then the EI function is supermodular. 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, policy) 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.
Complementarity between the two different practices of HRM/HPWP may be analysed by testing whether $EI_j = EI_j(h', h'', \theta_j)$ is supermodular in h' and in h''. Since each firm is characterized by specific exogenous parameters (θ_j), even if the maximization problem is the same for all the firms, the EI function may result supermodular in h' and in h'' for some firms, but not for others.
Our aim is to derive a set of inequalities (as those explicated in equations (1) and (2)), that can be used in empirical tests, to verify whether these inequalities are accepted by the data and, hence, whether in firms EI processes complementarities among different HRM practices is empirically confirmed, or in which specific circumstances (firm-specific exogenous parameters) complementarity holds.
More specifically, through the supermodularity approach we want to verify the first phase (the second being the intensity of innovation) of the EI process (Mohnen and Roller, 2005), that is how the firm's adoption probability of EI is significantly influenced by the presence of complementarities among HRM/HPWP practices.
So, if in its EI maximizing problem, a firm chooses to adopt none of the two practices we have $h' = 0, h'' = 0;$ in this case the element of the set H is $h' \wedge h'' = \{00\}.$ If a firm chooses to adopt both the HRM/HPWP practices, we have $h' = 1, h'' = 1;$, and the element of the set H is $h' \wedge h'' = \{11\}.$ Including also the mixed cases, we have four elements in $H = \{\{00\}, \{01\}, \{10\}, \{11\}\}$.
From above we can assert that h' and h'' are complements and hence that the function EI_j is supermodular, if and only if:

(4) $$EI_j(11, \theta_j) + EI_j(00, \theta_j) \geq EI_j(10, \theta_j) + EI_j(01, \theta_j),$$

or:

(5) $$EI_j(11, \theta_j) - EI_j(00, \theta_j) \geq \left[EI_j(10, \theta_j) - EI_j(00, \theta_j)\right] + \left[EI_j(01, \theta_j) - EI_j(00, \theta_j)\right],$$

[13]From equations (1) and (2) it is evident that complementarity is symmetric: having *more* of x' *increases* the returns to having *more* of *x''*, as well as having *more* of *x'' increases* the returns to having *more* of *x'*.
[14]The mathematical approach to complementarity typically considers two independent variables only. Actually the relationship of complementarity may involve more than two variables simultaneously, also through a chain reaction that starts from a complementarity relationship between two variables and involves a complementarity relationship between one of the two variables and a third variable and so on.

that is, changes in the firm's environmental innovation processes (adoption of EI) when both forms of HRM practices are increased together are more than the changes resulting from the sum of the separate increases of the two kinds of practice. Actually, the increases in EI due to an increase of both h' and h'' from $\{00\}$ to $\{11\}$ are greater (or at least equal) than the sum of the increases in EI due to separate increases of h' and h'' from $\{00\}$ to $\{10\}$ $(\{01\})$.

Summing up, complementarity among the two decision variables (h' and h'') exists if the EI_j function is shown to be supermodular in these two variables and this happens when either inequality (4) or inequality (5) or other derived inequalities are satisfied.

Related to the concept of complementarity is its opposite, that is the substitutability relationship (that is doing more of one activity reduces the attractiveness of doing more of the other activity). We can hence test if a substitutability relationship exists if :

$$(6) \qquad EI_j(11,\theta_j) - EI_j(00,\theta_j) \leq \left[EI_j(10,\theta_j) - EI_j(00,\theta_j)\right] + \left[EI_j(01,\theta_j) - EI_j(00,\theta_j)\right],$$

that is, changes in the firm's environmental innovation process when both forms of HRM practices are increased together are less than the changes resulting from the sum of the separate increases of the two kinds of practice.

Of course the two different types of relationship have different management and eventually policy implications. In fact, in the case of complementarity between two different HPWP/HRM practices if one of two practices is increased, it will be more attractive for the firm's environmental innovation to increase the other practice too, in the case of substitutability exactly the opposite holds. That is if one of two practices is increased, it will be more attractive for the firm's environmental innovation process to decrease the other practice, since it would be a waste in the firm's maximizing problem to increase both the practices simultaneously.

3. Data and empirical strategy

The empirical context of this work is the manufacturing sector in the Emilia-Romagna region in Italy (NUTS 2 level), which, with a population of around 4.5 million, 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 (with Lombardy) in the Italian context and it is classified as a medium-high innovator region at the EU27 level (Brusco, 1982; 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, which can be considered, to some extent, the frontier of the innovation for the firms.

For the reasons above, the answer to the main research question is based on micro level data coming from a unique dataset concerning a sample of 555 manufacturing firms with at least 20 employees located in Emilia-Romagna. The information collected through a structured questionnaire refer to the period 2006-2008. The sample is constructed on the basis of a stratified random sampling technique, in order to get reliable results for the overall regional manufacturing context, with a stratification by province (geographic location), size and sector (tab.A1 in Appendix). It is worth stressing again the proximity of our questions with that included in the CIS5 (Community Innovation Survey) carried out in 2008, which may allow direct comparisons with data collected at the European level on some specific issues. However, the information set provided by the questionnaire administered to firm's management is even richer than that secured by the CIS, concerning several sets of firms activity spanning issues and themes, such as technological and organizational changes, training activities, ICT implementation, environmental innovation and

internationalization strategies as well as the quality of firm level industrial relation and working condition, among which we focus on EIs and on HPWP/HRM practices in order to answer our research question as described below.
The parts of the questionnaire that we exploit in this paper are those referring to EIs adoptions, as outcome (dependent) variables, and HRM/HPWP aspects, as explicative variables among which to test the presence of complementarities as depicted in the above section. In what follows a detailed description of the variable is provided.

EI variables
The outcome variables derive from a set of questions concerning the EI activities carried out by the firms in 2006-2008. Since the EI issue is rather new a note is worth. Available definitions of EI (Kemp and Pearson, 2007) seems to mainly point to the 'eco' attributes of single new processes, products and methods to be evaluated on a technical and ecological side. For example, in the MEI (Measuring EI) research project 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 organisation (developing or adopting it) and which results, throughout its life-cycle, in a reduction of environmental risks, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives". Although the definition of EI is close to the one of environmental technologies, defined as "all technologies whose use is less environmentally harmful than relevant alternatives", it is not only about specific technologies, and includes also new organizational methods, products, services and knowledge oriented innovations. Organisational methods are also closely linked to education and training, and then human capital. EI is then neither sector nor technology specific and it can take place in any economic activity, not only in the still loosely defined 'eco-industry' sectors. It is not limited to environmentally motivated innovations, but includes "unintended' eco-effects of all innovations. Thus, when taken outside its purely technical dimension of (improved) environmental impacts, EI display a *systemic and behavioural dimension* that is consistent with both the conventional economic approach to innovation tout court and the results from the extensive evidence on the systemic dimension of EI itself (e.g. Horbach 2008). Thus, reconciling the need for sound techno-ecological measures of single EIs, and eco-impact of all innovations, with the economic dimension of EI as a behavioural process is probably the most challenging issue of research on EI. In formulating the questions relative to EIs we stuck to the MEI guidelines that informed the CIS5. For such reason we have at our disposal information (tab.1) concerning the reduction of energy and material for unit of product (ENERGY), the emissions reduction in terms of CO2, the emissions reduction to ameliorate the quality of soil, water and air (EMISSIONS) and, finally, the adoption of procedures like EMAS, ISO14001 and other, aimed at improving the environmental quality of the production process.
In tab.1 the distribution of EI in our sample is shown[15]. An expected result emerges when the overall sample is restricted to only those firms belonging to polluting sectors (Marin and Mazzanti, 2011): manufacture of coke, refined petroleum products and nuclear fuel; manufacture of chemicals, chemical products and man-made fibres; manufacture of other non-metallic mineral products and manufacture of basic metals and fabricated metal products, which are respectively classified as DF, DG, DJ, DI according to a two-digit NACE-REV1 classification[16]. In fact, while the presence of EIs is really low in the overall sample, it gains several percentage points in

[15] In order to verify the robustness of our survey, it is worth stressing the consistency between the diffusion of EI in our sample and the data on EI from the newly released Community Innovation Survey (ISTAT sources) database that covers 6483 Italian manufacturing firms, which shows adoption in a 13-18% range across sectors and type of EI. Adoptions in the North east to which the region belongs are 19% for energy efficiency and 15% for CO2 abatement (18% and 14% Italy as a whole). Data for comparison are available upon request.
[16]Because of aggregation constraints in the collection of information through our unique survey we are forced to include in the set of polluting sector also the sector DH (Manufacture of rubber and plastic products).

distribution frequency when only the polluting sectors are considered, passing from an average of 14% to 20%.
Indeed, our analysis proceed both looking at the entire working sample of 555 firm and at the sub-set of it composed by the polluting sectors (192 observations), in order to overcome potential distortions in our results stemming from the utilization of an exclusive analysis on the whole sample of interviewed firms, neglecting the importance of distinguishing the most polluting sectors, which are those more challenged by environmental regulations and possibly on the frontier of EIs adoption.

Tab.1: Adoption of environmental-innovations (distribution)

	Whole sample		By Polluting Sectors^	
Variables (Dummies)	Freq.	%	Freq.	%
Energy/Material reduction per unit of product (**ENERGY**)	82	14.77	43	22.4
CO2 reduction (**CO2**)	64	11.53	33	17.19
Emissions reduction for soil, water and air (**EMISSIONS**)	78	14.05	41	21.35
Adoption of procedures like EMAS and ISO14001 (**EMASISO**)	80	14.41	36	18.75
Obs./mean %	555	13.69	192	19.92

^Two digit classification: DF, DG, DJ, DI (and DH)

HPWP/HRM variables
The search for complementarities among HPWP/HRM practices is an important issue in understanding EI dynamics. The perspective here adopted encompasses internal to the firm drivers of EIs, where the complementary nature of different organisational elements may be useful in explaining the presence of EIs at the firm level, allowing to integrate technical measurements of single EI within an economic perspective looking at the firms as 'eco-innovating actors', which adopt synergic strategies potentially capable of increasing the absorptive capacity of the organisation towards EIs. Three sets of organisational aspects that can be brought back to the wider concept of HPWP/HRM practices are here taken into consideration (tab.2): changes in production organisation (ORGPROD), changes in labour organisation (ORGLAB) and training activities (TRAINCOVERAGE, TRAINCOMP, TRAININVEST).
Starting from the organisational changes sets of variables, the questions that were addressed to the management provided us the possibility to construct composite additive indexes of intensity in organisational changes: the more organisational changes, both in production and labour organisation, are implemented, the higher the index. The items included in the indexes construction are associable to the set of items usually ascribed to HPWP practices in the literature, such as, for example, the introduction of team working and quality circles as for production organisation, and improvement of competences, increase of workers autonomy and problem solving, reduction of hierarchical layer as for labour organisation. For purposes linked to our analysis the indexes were dicotomised according to the following rule: if the index was above or equal to the mean (median) then we assigned the vale 1, while we assigned the value 0 otherwise. We note that the necessary dichotomisation of indexes and continuous variables is performed, to check sensitivity of results, both using the mean and median as statistics as clearly evidenced in section three below.
As for the training activities, which clearly refer to HRM practices, we exploit information concerning the percentage of employees covered by training programmes (TRAINCOVERAGE), a variable that tells us whether the firm introduced training courses in order to develop the entire range, not just some of them, of competences (TRAINCOMP) listed in the questionnaire (technical,

on informatics, organisational and on economics/law) and finally a variable that inform us whether the firm invested its own economic resources in training activities (TRAININVEST).

Tab.2: HPWP/HRM variables (distribution)

	Whole sample		Polluting Sectors^	
Variables (Dummies)	Freq.	%	Freq.	%
HPWP				
Production organisation aspects (ORGPROD)	350	63.06	127	66.15
Labour organisation aspects (ORGLAB)	218	39.28	83	43.23
HRM				
Employees involved in training activities (TRAINCOVERAGE)	209	37.66	87	45.31
Full set of competences covered by training activities (TRAINCOMP)	58	10.45	18	9.38
Presence of resources investmed in training (TRAININVEST)	408	73.51	153	79.69
Obs./mean%	555	40.23	192	44.40

^Two digit classification: DF,DG,DJ,DI (and DH)

On the basis of such dicotomised HPWP/HRM variables we were able to define four states of the world for couples of such variables according to their joint presence/absence, as it is shown in tab.3, where the distribution of the firms for each state of the world is reported. Those are the 'states' we exploit for complementarity assessments as described in section two.

Tab.3: HPWP/HRM states of the distribution

		States of the world (555 obs.) Whole sample %				States of the world (192 obs.) Polluting Sectors^ %			
Variables (Dummies)		(1,1)	(1,0)	(0,1)	(0,0)	(1,1)	(1,0)	(0,1)	(0,0)
TRAINCOVERAGE	ORGPROD	26.67	10.99	36.40	25.95	31.77	13.54	34.38	20.31
TRAINCOVERAGE	ORGLAB	21.44	16.22	17.84	44.50	27.08	18.23	16.15	38.54
TRAINCOMP	ORGPROD	8.47	1.98	54.59	34.95	7.81	1.56	58.33	32.29
TRAINCOMP	ORGLAB	7.57	2.88	31.71	57.84	6.25	3.13	36.98	53.65
TRAININVEST	ORGPROD	49.37	24.14	13.69	12.79	55.73	23.96	10.42	9.90
TRAININVEST	ORGLAB	32.97	40.54	6.31	20.18	36.46	43.23	6.77	13.54

^Two digit classification: DF, DG, DJ, DI (and DH)

Controls

In addition to the main explicative variables we use a standard set of controls that includes size dummies, a là Pavitt/OECD taxonomy for sectors[17] and less standard aspects related to the firms' strategic behavior such as the "openness" to international markets provided by a variable indicating if a firm is an associated company of a foreign one (INTERN_OPEN) and the kind of such association (e.g. joint venture, stake below or above 50%), the presence of resources invested in R&D (R&D) and an index capturing the intensity in collaborations for technological innovations (TECH_NET) (for descriptive statistics see tab.A2 in Appendix). The ratio behind the use of such variables is that they may constitute influencing structural and strategic factors for EI adoption: the openness to international markets as well as effort devoted to R&D activities and to collaborations for technological innovations may represent positive impulses.

[17]We choose to use such sector taxonomy, instead of the two digit NACE REV1 we also have at our disposal, in order to reduce the number of controls.

On the basis of the theoretical framework for complementarities assessment we set up the following procedure in two steps in order to investigate the extent to which HRM and HPWP interact and eventually drive the adoption of EIs.
At first we define our empirical model as follows:

$$[7] \quad [EI]_i = b_{0i}[Controls] + b_{1i}[HPWP(1)/HRM(1)] + b_{2i}[HPWP(1)/HRM(0)] + b_{3i}[HPWP(0)/HRM(1)] + b_{4i}[HPWP(0)/HRM(0)] + u_i$$

where the EI dummy variables enter as dependents of our probit regressions[18], the HPWP/HRM variables are included as couples capturing the different states of the world as defined above; the constant term is suppressed in order to get coefficients for a each state of the world; *i* stand for the *i-th* firm. Matching the HPWP/HRM factors generates six HPWP/HRM couples that we regress for the four EI dependents: 24 cases.
Thus, the second step of the analysis is to check the complementarity /substitutability hypothesis implementing one sided t-tests on the coefficients associated to 24 cases. In our model, for each couple of HPWP/HRM the complementarity holds if $b1+b4-b2-b3 \geq 0$. This complementarity /substitutability hypothesis is also tested for the polluting sectors, following the same procedure and carrying out further 24 tests. The aim is to check whether for the more environmentally problematic but also more innovative sectors, the complementarity assessment change.

4. Empirical analysis: Complementarity assessments

4.1 All sectors

Table 4 clearly shows that the critical value of the one-sided t-test (1.645, 5% level of significance)[19] is slightly surpassed for CO2 reduction. Nevertheless, the evidence does support strict substitutability instead of complementarity, and we observe significance only in one case, re-confirming the strong specificity of complementarity existence[20]: training competencies – changes in re-organization of production. The two seem not to match well for the aim of increasing the adoption of EIs: either lack of 'green'-oriented competencies (environmental business, environmental law, environmental engineering) or a business as usual application of (rather old) HPWP practices, without including environmental objectives (e.g. material reductions or energy efficiency associated with production on demand) are the most likely explanations. Further research that jointly uses case studies and econometrics is necessary in the future. This is nevertheless a message that is useful for firms and managers to rethink their processes.

[18] Full probit regressions are available upon request from the authors.
[19] The two tailed test on the inequality has as null hypothesis, depending on the direction of the inequlity (=<; >=) either 'complementarity' or 'substitutability'. This means that the non rejection of the null cannot allow an inference on the strong or weak content of those. The rejection of the null respectively means 'strong substitutability' and 'strong complementarity'. In other words, strong complementarity is assessable as a rejection of the null when testing substitutability. The two tests are obviously 'complements' and are based on the same t statistics.
[20] We also checked whether a different definition of organizational change variables may affect the results. Namely, instead of using the mean we assign value one to firms that just adopt some kind of organizational strategy. This less restrictive assumption does not affect the main evidence.

Tab.4: Complementarities tests in a discrete setting. One sided t-tes values on the EI regression coefficients

		ECOINNO			
HPWP/HRM variables (Mean for dicotomisation)		ENERGY	CO2	EMISSIONS	EMASISO
TRAINCOVERAGE	ORGPROD	-0.03	0.25	-0.14	-0.26
TRAINCOVERAGE	ORGLAB	0.34	0.43	0.21	0.14
TRAINCOMP	ORGPROD	-1.64**	-1.66**	-1.97**	-1.60**
TRAINCOMP	ORGLAB	0.11	-0.48	-0.02	0.54
TRAININVEST	ORGPROD	0.31	-0.29	0.00	0.76
TRAININVEST	ORGLAB	0.38	0.92	0.74	0.02
*HPWP/HRM variables (Median for dicotomisation)^*		ENERGY	CO2	EMISSIONS	EMASISO
TRAINCOVERAGE	ORGPROD	-0.34	-0.04	-0.26	-0.28
TRAINCOVERAGE	ORGLAB	0.49	0.68	0.32	0.07
TRAINCOMP	ORGPROD	-1.64**	-1.66**	-1.97**	-1.60**
TRAINCOMP	ORGLAB	-0.03	-0.58	-0.63	0.34
TRAININVEST	ORGPROD	0.31	-0.29	0.00	0.76
TRAININVEST	ORGLAB	0.06	0.61	0.57	-0.13

* Critical values of one-sided t-test: 1.645 and 1.282 (** 5% and * 10% level of significance respectively); N=555.
^Results using the median may be considered a sensitivity check

Though counter-intuitive, given that a full reorganisation of firm strategies may be expected to be relevant when coping with innovations new to the firm, this could also be coherent with recent evidence that shows how training (but alone) is a determinant of EIs (Horbach, 2008; Cainelli et al., 2011a,b). It is a signal of potential weaknesses and difficulty in the organizational change firms face. Recalling that only 10-20% of firms adopt EIs, we believe that the intuition is that single factors are needed and responsible of adoptions by leaders/early movers (training within internal strategies, other factors then, mostly external). Failures in setting up complementarities can act as a brake, especially in the short run and for firms of medium small sizes that more than others need to strengthen appropriability conditions through intangible non replicable investments. Complementarity is such an asset. Surely those smaller firms also need external cooperation to achieve higher levels of innovation, but the internal reorganisation of human resource management is also a step to carry forward, as a knowledge based 'asset' they can exchange in the market or when cooperating with firms and institutions.

The evidence for CO2 and energy material reductions are quite similar. As far as the latter case is concerned, we cannot end up with 'strong' signals of neither complementarity nor substitutability. This is also true for another quite radical, not so diffused, innovation for Italian firms, such as environmental standards, which should instead be really embedded within changes of HRM and HPWP.

Substitutability even increase its intensity in the case of emission reductions, a relatively less radical form of innovation. Again, competencies and organizational changes in production are the mismatch situation.

Summing up, even though we observe some variation in evidence across different EIs, the main message the analysis provides is a critical weakness in the node 'competencies vs production organizational changes'. This is a potential brake to the diffusion of EIs, intuitively stronger for medium small sized firms.

Recalling back to the survey analysis by Ennen and Richter (2009), (strict) complementarity can be a source of significant competitive advantage, but it is really idiosincratic to the sector, innovation type and inputs to innovation or performance we analyse. The embeddedness in complex systems

makes it hard for complementarity to be managed purposefully. They in fact find that the evidence of (strict) substitutability among inputs, that is trade offs in firm strategies, is quite diffused. Though the match of heterogeneous factors is more likely to generate complementarity gains, they did not find a single factor whose co-occurrence with others invariably result in the emergence of complementarity relationships. We believe that at the current stage of development, environmental innovations, especially those regarding carbon dioxide abatement and closed material loops and waste reductions, are quite radical innovations, associated with an increase of the complexity of the firm environment.

4.2 More Polluting sectors

As anticipated above we test the hypothesis for more polluting sectors. The heavier regulatory burden and stronger exposition to international markets might increase the likelihood of using complementarity based strategies in the adoption of EIs.

The evidence in table 5 is somewhat different[21]. Though we do not observe any cases of strong complementarity, but strong substitutability is not present as well. For this sub sample of firms belonging to sectors that are on the 'frontier' of environmental challenges, the weakness regarding the linking of training competencies and organization of production is not relevant[22]. As an example of quite different evidence, in one case (training coverage – organization of production) we do find evidence in support of strong complementarity, even though only at the 10% significance level. This shows that complementarity is present as an option in the firm HRM/HPWP tool kit.

Firms at the frontier of environmental challenges do respond better than the average firm, though they still fail to exploit complementarities in extended and effective ways. The relative lack of diffusion of EI with respect to competitors (Germany), and as a consequence some difficulties that industrial Italian firms have encountered in recent years can be explained by this evidence. Important new technologies such as EI are only partially embedded within firms organizational change, even for the most innovative and urgently in need of EI adoptions. Exogenous or external sources of innovation have prevailed but in our eyes are not sufficient to assure a real diffusion in the system.

As we recalled at the beginning, this is highly in the spirit of the Porter idea of competitive advantages stemming from the extension of the firm's aims and the use of multiple ways to reorganize the structure. It is then possible that properly designed regulations bring about conditions such as boosting demand for green products, pricing scarce resources, making unexploited technologies available (Wagner, 2006) and open up the set of choices constrained by production habits towards a re-engineering of routines that allow low hanging fruits to be harvested. The target is not only referring to market prices, but ‘inside the firm failures’ should be tackled (Gabel and Sinclair-Desgagnè, 1999).

[21] Also in this case a sort of sensitivity analysis using the median to construct the dichotomous variables for the operationalisation of the state of the world has been conducted with no relevant differences in the results. The detailed results are available from the authors upon request.

[22] We also checked whether firms in sectors that have reduced emissions of CO2 in the last 20 years behave differently. Results do not change with respect to those of 'polluting sectors', probably given some overlapping (sectors that have reduced emissions are DB-DC; DF-DH-DG, DJ). In any case, substitutability is not braking EI here.

Tab.5: Complementarities tests in a discrete setting for polluting sectors. One sided t-tes values on the EI regression coefficients

		ECOINNO			
HPWP/HRM variables (Mean for dicotomisation)		**ENERGY**	**CO2**	**EMISSIONS**	**EMASISO**
TRAINCOVERAGE	**ORGPROD**	0.46	1.55	0.30	0.38
TRAINCOVERAGE	**ORGLAB**	0.71	0.47	0.38	0.95
TRAINCOMP	**ORGPROD**	-0.58	-1.14	-1.15	-0.43
TRAINCOMP	**ORGLAB**	-0.20	-0.44	-0.12	0.60
TRAININVEST	**ORGPROD**	0.86	0.52	0.41	1.29
TRAININVEST	**ORGLAB**	-0.51	n.f.	1.10	-0.10
*HPWP/HRM variables (Median for dicotomisation)^*		**ENERGY**	**CO2**	**EMISSIONS**	**EMASISO**
TRAINCOVERAGE	**ORGPROD**	0.22	0.94	0.09	0.16
TRAINCOVERAGE	**ORGLAB**	1.09	1.39	0.66	1.11
TRAINCOMP	**ORGPROD**	-0.58	-1.14	-1.15	-0.43
TRAINCOMP	**ORGLAB**	-0.37	-0.55	-0.91	n.f.(2)
TRAININVEST	**ORGPROD**	0.86	0.52	0.41	1.29
TRAININVEST	**ORGLAB**	-0.50	n.f.(1)	1.13	0.01

* Critical values of one-sided t-test: 1.645 and 1.282 (** 5% and * 10% level of significance respectively); N=192;
n.f.(1): the state of the world TrainInvest=0 and OrgLab=1 predict failures perfectly in the probit estimation, hence the variable is dropped and the t-test cannot be computed.
n.f.(2): the state of the world TrainComp=1 and OrgLab=0 predict failures perfectly in the probit estimation, hence the variable is dropped and the t-test cannot be computed
^Results using the median may be considered a sensitivity check

We believe that the evidence we here provide is explained by two main arguments. First, firms have tended to rely on single factors (structural ones such as sector specific features, training, cooperation with clients or universities, etc..) to adopt the environmental innovations they needed. This is well documented in the EI literature. External factors, including foreign-related ones, have thus predominated. Nevertheless, this does not appear to be sufficient to increase the adoption of green innovations and their diffusion. The share of EI firms is, even in a high perform industrialised region such as Emilia Romagna, definitely low. Internal drivers, as the reorganisation of firm production and HRM is also needed. Large firms, that on average show higher intensity of EI adoptions, may well exploit the complementarity benefits to further extend the scope (more variety of) of the environmental innovations they adopt. This can also generate complementarity benefits at the level of environmental innovations integration, that can produce effects on economic and environmental gains. This is surely a further issue for researchers.

Small and medium firms need to invest on internal factors even relatively more, to set up a framework where green strategies are embedded within organizational changes of the firm. Public supports, which is justified by the many market failures (environmental innovation related) that are involved, is possibly needed in the first phase of adoption. Nevertheless, the creation of complementarity links is in itself an intangible asset that increases firms capability of appropriating innovation rents. One way is that a strong 'complementarity' value generated within the firm through proper matching of factors of change increase the bargaining power of firms when they cooperate and exchange knowledge with other firms and institutions. Complementarity is thus an element of asset diversification, which makes the firm less reliant on external sources of knowledge, and may well increase the diffusion of green technologies.

5. Conclusions

In the aim of providing new understanding of the effects of firm's organizational change and fill gaps in the literature of EIs, we study the relationships between human resource management and internal processes of organizational change in labour and production through the lens of complementarity theory. Though the relevance of HPWP/HRM for developing relatively new and radical forms of innovations such as EI has been noticed by scholars that contributed to the development of the Porter hypothesis, the lack of integration between environmental economics and HRM disciplines has halted research in this specific realm.

We analyse 24 situations of potential complementarity between training and organizational changes, covering 4 different types of EI (CO2, emissions, EMS/ISO, energy/material). We show that for EI adopted by firms located in a densely industrial region of the European union exposed to international competition, strict complementarity is rarely present. When looking at the full sample of firms, strict substitutability instead emerges as a potential brake for EI. In our case, training of key competencies and organizational changes in production seem to suffer from a mismatch, that highlights how green strategies are not embedded within firms reorganization changes. This means that even firms that invest more than others are excluding green contents from their strategies.

This confirms the well known fact that complementarity is not to be taken for granted: it is industry, innovation and factor specific. Its achievement and the relative benefits need a full screening of firms existent and non existent assets, proper investments in the engineering of the firm organization. It can be a low hanging fruit, though the tree is eventually tall and steep.

Firms that are on the frontier of environmental technological challenges (more polluting firms, heavier regulated firms) present a different evidence. In this case, the weaknesses of substitutability disappears, and some sign of complementarity emerges (for CO2 abatement, through training coverage and organization of production strategy). Sector specificity and different market conditions, including heavier environmental regulations, influence the way firms think and behave with respect to the setting up of (green oriented) complementarity investments. This evidence is coherent with the Porter hypothesis. We observe complementarity related adoption of EI as an element of organisational change in firms that are subject to more stringent regulations.

Overall, industrial firms have probably tended to rely on single factors (structural ones such as sector specific features, training, cooperation with clients or universities, etc..) to adopt the environmental innovations they needed. External factors, including foreign-related ones, have thus predominated. Mere compliance strategies dominated processes of full reshaping of the organization to achieve new competitive advantages. This does not appear to be sufficient to increase the adoption of green innovations and their diffusion. The share of EI firms is, even in a high perform industrialised region such as Emilia Romagna, definitely low. Internal drivers, as the reorganisation of firm production and HRM are also needed. The creation of complementarity links is in itself an intangible asset that increases firms capability of appropriating innovation rents and then their capability to self-sustain in competitive markets where new innovations are to be adopted to cope with competitive pressures, partner's requirements, regulatory interventions. A strong 'complementarity' that is generated within the firm through proper matching of factors of change also increases in our eyes the bargaining power of firms (since their intrinsic value is higher) when they cooperate and exchange knowledge with other firms and institutions.

Future research efforts should further investigate if a relationship of complementarity exists among EI, and between EI and other techno-organizational changes, and how this complementarity influence the firm’s performance (e.g. the average productivity).

Appendix

Tab.A1: Population and sample distribution (%) by sector and size

Population distribution (%)	Size					
Sector	20-49	50-99	100-249	250+	*Total*	*Total (a.v.)*
FOOD	5,65	1,94	1,16	0,64	9,39	*382*
TEXTILE	6,17	1,47	0,71	0,37	8,73	*355*
WOOD, PAPER AND OTHER INDUSTRIES	7,79	1,67	0,79	0,42	10,67	*434*
CHEMICAL AND RUBBER	5,01	1,87	1,11	0,42	8,41	*342*
NON METALLIC MINERAL PRODUCTS	3,81	1,23	1,18	0,79	7,01	*285*
METALLURGY	16,99	3,29	1,18	0,25	21,71	*883*
MACHINERY	21,44	6,37	4,06	2,24	34,10	*1387*
Total	66,86	17,85	10,18	5,11	100,00	
Total (a.v.)	*2720*	*726*	*414*	*208*		*4068*
Sample distribution (%)	Size					
Sector	20-49	50-99	100-249	250+	*Total*	*Total (a.v.)*
FOOD	2,88	3,78	1,62	0,54	8,83	*49*
TEXTILE	2,70	1,44	1,62	0,54	6,31	*35*
WOOD, PAPER AND OTHER INDUSTRIES	3,60	2,88	1,08	0,90	8,47	*47*
CHEMICAL AND RUBBER	3,78	3,42	1,80	1,08	10,09	*56*
NON METALLIC MINERAL PRODUCTS	1,62	2,16	1,62	2,16	7,57	*42*
METALLURGY	8,83	5,77	2,16	0,18	16,94	*94*
MACHINERY	14,05	15,32	7,39	5,05	41,80	*232*
Total	37,48	34,77	17,30	10,45	100,00	
Total (a.v.)	*208*	*193*	*96*	*58*		*555*

Tab.A2: 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
CO2 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/HRM						
Production organisation aspects (ORGPROD/HPWP)	0.630	0.483	0/1	0.661	0.474	0/1
Labour organisation aspects (ORGLAB/HPWP)	0.392	0.488	0/1	0.432	0.496	0/1
Employees involved in training activities (TRAINCOVERAGE/HRM)	0.376	0.484	0/1	0.453	0.499	0/1
Full set of competences covered by training activities (TRAINCOMP/HRM)	0.104	0.306	0/1	0.093	0.292	0/1
Presence of resources investmed in training (TRAININVEST/HRM)	0.735	0.441	0/1	0.796	0.403	0/1

Controls						
Size dummies	/	/	0/1	/	/	0/1
Sector dummies	/	/	0/1	/	/	0/1
INTERN_OPEN	0.021	0.066	0/0.83	0.016	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

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