CO_2-reducing innovations and outsourcing: evidence from two "green industries" in North–East Italy

Riccardo Leoncini[*]

Sandro Montresor[#]

Francesco Rentocchini[§♣]

[*] Department of Economics, University of Bologna (I). E-mail: riccardo.leoncini@unibo.it

[#] Faculty of Economics and Law, Kore University of Enna (I). E-mail: sandro.montresor@unikore.it

[§] Southampton Business School, University of Southampton (UK). E-mail: f.rentocchini@soton.ac.uk

[♣] Corresponding author: 28/2027, University of Southampton, Highfield Campus, SO17 1BJ, Southampton (UK)

Abstract

This paper investigates whether firms' outsourcing impact on innovations aimed at a reduction of their CO_2 emissions. This topic is assuming increasing relevance for environmentally sustainable business strategies and the resulting patterns of growth. Based on our theoretical premises, we look for empirical evidence in two 'green' sectors (sustainable buildings and photovoltaics) within a regional context where outsourcing is a pervasive business strategy (i.e. North–East Italy). While the reduction of vertical integration that outsourcing entails appears to have an irrelevant role, a CO_2 reducing impact is found for the externalisation of tangible activities, contrary to that of intangibles that even increases it. Results are extremely robust in econometric terms, and point to some interesting environmental implications of the standard "make–or–buy" issue in industrial organisation.

Keywords: environmental innovations; CO_2 reduction; outsourcing.

JEL codes: Q55, 032, L23, L24.

1. Introduction

The reduction of CO_2 emissions is nowadays one of the firmest policy targets towards the achievement of a sustainable economic growth. In the European Union, a legislation package has been set within the Europe2020 strategy to encapsulate such a key–objective into a verifiable specific target (i.e. one of the three ‘20-20-20”’ targets). In the business realm, this and other initiatives across the World (such as, for example, the EPA regulatory actions in the US) are expected to reduce the ‘CO_2 footprint’ of firms. One channel through which this could occur is by inducing firms to introduce and/or adopt eco– innovations (EIs) that lead to a reduction of their CO_2 impact (in brief EICO2).

EICO2 are eco–innovations for which present and future regulations are among the most important drivers (Horbach, 2008). Indeed, with respect to these EIs, environmental standards, legislations and agreements (like the Kyoto protocol) have been found to exert an important “push/pull effect” on the firms’ incentives to curb a socially excessive EICO2 footprint and a socially insufficient amount of (R&D) knowledge for its reduction: the so-called, “double-market-failure” typical of EIs (Jiménez, 2005; Del Rio Gonzalez, 2009). However, recent studies from diverse backgrounds (e.g. ecological and innovation economics) have met and shown that regulations do not play alone in the EI realm, and rather interact with other drivers, a number of which concern the inner characteristics of the eco-innovating firms, such as its R&D capacity, its organisational practices, its external stakeholders, just to mention a few (Horbach et al., 2012). Intensive research efforts have been carried out in this direction, which have nearly balanced the wide number of those identified with respect to standard technological innovations. Still, some mismatch remains in their respective analysis, such as, for example, about the (eco-) innovative role of external or interactive kind of drivers (e.g. Ghisetti et al., 2014). In particular, and quite surprisingly to us, no attention has been devoted so far to the possible EI implications of the firm's decisions to externalise, that is outsource, part of their business activities and of the consequent reduction of their degree of vertical integration.[1] As is well known, this has become a quite topical relationship for standard innovations (e.g. Robertson and Langlois, 1995; Windrum et al., 2009). And the relevance for EIs, and EICO2 in particular, is at least factually relevant. The choice of having activities formerly carried out inside the firm, performed by an external supplier (McIvor, 2005), has in fact a crucial impact on the firms' level of emissions. Providing transaction costs are not prohibitive, outsourcing can entail efficiency gains from which firms can benefit in channelling both their tangible and intangible internal resources

[1] While stating this point, we are aware of the amounting literature on the impact that international outsourcing (i.e. offshoring) has been claimed to have on the environmental performances of firms, which use it for relocating activities with a high CO_2 impact from their "home" country to relatively less regulated "host" ones through FDIs: the so–called "Pollution Haven Hypothesis" (PHH) (a still inconclusive evidence of it can be found in Jeppesen et al. (2002); Brunnermeier and Levinson (2004); Levinson and Taylor (2008); Wagner and Timmins (2009). However, this is a quite different research question from our own, related to the environmental role of regulatory asymmetries across countries, rather than to outsourcing per se. Furthermore, the "confounding" effect of the PHH gets substantially reduced when, as it is in our empirical application: i) the focal firms of the analysis are locally inter-connected and characterized by a very low level of penetration of international markets; ii) the relevant dependent variable is not the amount of CO_2 emissions, but rather the introduction of innovations, whose primary purpose is to reduce or even eliminate the same kind of emissions; iii) the industrial context of analysis is represented by sectors, which are involved in the production of environmentally sustainable goods and commodities. For all of these reasons, on which we will return in Sections 2 and 3, outsourcing can hereby be seen as a "firm–specific" factor that adds to, rather than eluding, the regulatory drivers of $EICO_2$.

towards EICO2 investments. What is more, providing suitable coordination mechanisms are in place, by means of outsourcing firms can tap into external providers for (tangible and intangible) EICO2 resources not available in-house.

In spite of this relevance, the impact of outsourcing and of vertical disintegration on EICO2 has been surprisingly under-investigated and represents a research gap that the present paper intends to fill. In particular, the research questions addressed are the following: (i) Does the firms degree of vertical disintegration affect the capacity of reducing the CO2 footprint through eco–innovative activity? (ii) Does the externalized activities affect this specific eco–innovative capacity? Addressing these questions would increase our knowledge of the possible scope that some apparently unrelated industrial policies (e.g. trust and competition) and strategic actions (e.g. networking and open-innovation) can have in achieving environmentally sustainable objectives of the kind of CO2 reduction.

The paper is structured as follows. In Section 2 we review the literature on (standard) innovation and outsourcing, and try to extend its results to the case of EICO2, by putting forward our research hypotheses. In Section 3 we present the empirical application with respect to which we test our hypotheses: an original sample of 182 firms, operating in the sustainable building and photovoltaic sectors, in four North–East Italy regions (Emilia Romagna, Friuli Venezia Giulia, Trentino Alto Adige and Veneto). Section 4 illustrates the results. Section 5 concludes with some comments on the relevance and on the possible future extension of our results.

2. Theoretical background

In industrial organization and innovation studies, the implications of outsourcing for the technological capacity of the firm have been subject to intense investigation. From both of these research streams a set of results have emerged, whose extension to the case of EI, and EICO2 in particular, has not been scrutinised yet. Given the influence policy makers can have on the firms' choices of modifying their boundaries with respect to the market and their organisational setting, and the strategic role it plays as a business strategy in search of a competitive advantage, this is to us quite unfortunate. Establishing a significant correlation between EICO2 and outsourcing would actually enlarge the set of policy/strategy tools for firms to pursue a Porterian "win-win" effect (Ambec et al., 2013).

In the absence of specific studies on the topic, the only way to proceed is drawing eclectically on the literature about "standard" innovation and outsourcing, and looking for possible specifications and/or amendments of its results, which the particular nature of EICO2 would require. In doing so, we start by recognising that the impact outsourcing can have on innovation is not unambiguous in the extant literature. The conventional "wisdom" that vertical integration provides an advantage in introducing new products/processes (mainly in terms of transaction costs, economies of scale, and organizational coordination) has been disputed by considering the benefits that outsourcing firms could have by establishing various forms of network relationships with their providers and by experimenting with them different processes of resource-sharing and learning-by-interacting (Robertson and Langlois, 1995; Windrum et al., 2009). The desirability of outsourcing vs. vertical integration in terms of innovation needs to be established on a more specific basis and depends, among the others, on: i) the kind of innovation it could bring to; ii) the characteristics of the industry in which it occurs; iii) the nature of the externalised activities.. Let us address each of them in turn.

2.1. Kind of innovations: incremental vs. radical

Among the different characteristics of technological innovation, the most sensible in terms of outsourcing has appeared its degree of novelty, and the distinction between incremental and radical innovations. Substantial technological breakthroughs require firms to face a great deal of uncertainty and to undertake strongly interdependent development efforts by different functions, and would thus be inconsistent with the decentralisation logic of outsourcing (Gonzalez-Diaz et al., 2000). On the contrary, incremental innovations, and even less incremental innovations that require for example the rearrangement of existing elements in a new architecture (Henderson and Clark, 1990), could benefit from outsourcing through the diversity of information signals and competencies of the providers (Robertson and Langlois, 1995; Mahnke, 2001).

Extending this argument to the EI realm is far from automatic. The requirement of a "reduced environmental impact" for an EI actually introduces additional dimensions, with which the distinction between incremental and radical innovations should be enriched, such as the typology of the impact, or its so-called "design rationale" (Picazo-Tadeo and García-Reche, 2007). One alternative in this respect could be to look at the "eco-efficiency" of an EI – in terms of environmental impact per unit of product or service value (WBCSD, 2012).[2]

---

[2] On this basis, interesting classifications have been proposed. See, for example, Brezet (1997) and Ehrenfeld (2001).

However, this requires the reference to specific instances of EI and would not be suitable for our more generic focus on a typology of them, like our focal innovation, that is EICO2. More useful in this last respect is the ladder of EI design rationales put forward by Carrillo-Hermosilla et al. (2010), ranging from "component addition", through "sub-system change", up to "system change". [3]

Although with the benefit of hindsight, due to the inner heterogeneity of EICO2, it can be argued that most of EI which have been so far introduced in this realm, fit at least with the intermediate level (sub-system change), aimed at "reducing negative impacts by creating more goods and services, while using fewer resources and generating less waste and pollution" (Carrillo-Hermosilla et al., 2010, p. 1076). Indeed, extant EICO2 can in general be considered less incremental than the pure "development of additional components to improve environmental quality, as with "end-of-pipe" technologies" (p. 1076). However, given the targets of reductions that are currently envisaged EICO2 are also less radical than the "redesign of entire systems towards more "eco-effective" [and not only eco-efficient] solutions" (p. 1076).

Taking the dichotomy between radical technological change and outsourcing as a benchmark, we conjecture that EICO2 does not entail (yet) such a substantial degree of novelty and of environmental impact to require vertically integrated organizational structures to be pursued.[4]

---

[3] Carrillo-Hermosilla et al. (2010) also consider other classificatory, though less pivotal dimensions, like the user, the product service, and the governance dimensions.

[4] Our conjecture is consistent with the recent appraisal of the three technological trajectories of CO2 capture envisaged at the time of this writing, that is: post-combustion, oxy-fuel combustion, and pre-combustion. The first two, which are used in CO2 capture and storage (CCS) plants, are deemed purely incremental improvement

On the contrary, we expect that, as in the case of technological innovations, a higher outsourcing extent could be helpful to firms willing to experiment with their providers more eco-efficient solutions and more optimal sub-systems in terms of CO2 emissions.

On the basis of the previous argument, we put forward our first research hypothesis that reads:

HP1: *In general, $EICO_2$ could benefit from a higher degree of firm's vertical disintegration.*

2.2. Industry characteristics: Schumpeter Mark I vs. Mark II

Another important element of the impact of the firms' degree of vertical disintegration on innovation is the industry environment in which they operate, in particular in terms of technological regimes and sectorial systems of innovations (Breschi et al., 2000). Depending on the joint characteristics they reveal in terms of technological opportunities, appropriability conditions, cumulativeness, and knowledge base properties, industries can be shown to follow different patterns of technological development, in which outsourcing plays a different role. In some industries – Schumpeter Mark I regime (or "entrepreneurial regime") – innovation follows a pattern of "creative destruction", in which the technological quasi-rents of the incumbents are continuously wiped out by new enterprises bringing into the market new ideas and innovation (Malerba and Orsenigo, 1995, p. 85). In this dynamic setting,

---

of coal power plants. Only the third, used in Integrated Gasification Combined Cycle (IGCC) power plants, is considered radical, but still in need of not yet available components (e.g. gasifier and gas turbine) (Rennings et al., 2013).

outsourcing can be functional to access external knowledge and competencies, and to speed–up learning and innovation, even at the cost of some possible knowledge leakage (Mahnke, 2001, p. 368-69). In some other industries – Schumpeter Mark II regime ("routinised regime") – innovation is instead driven by "knowledge accumulation", as new ideas builds gradually and incrementally on pre-existing ones. In this more stable setting, outsourcing is less pivotal to promote innovation. To be sure, it could be even detrimental to it, as the entailed problems of knowledge leakage with respect to the providers could expose the client firms to the imitation attempts of the competitors. Outsourcing appears even more pivotal in more detailed regimes classifications, which address more explicitly the characteristics of the knowledge bases and the sources of barriers to entry. In the taxonomy proposed by Marsili (2002), for example, outsourcing is a key innovation element in "complex systems" regimes, as distinguished from science-based, fundamental processes, product engineering and continuous processes.

Thinking of outsourcing as favouring (hampering) innovation in dynamic (cumulative) regimes, we expect that the specific kind of sectorial systems of innovation that we address might reinforce (attenuate, if not even reverse) the EICO2 impact we have put forward in HP1.

2.3. Externalised activities: tangibles vs. intangibles

Another aspect to consider is the kind of activities that are externalised, and the different impact that different outsourcing projects have on the innovation capacity of the firm. Going beyond the vertical disintegration degree of the firm – as it might be captured by the number of its externalisation operations – one should consider the implications of buying rather than making a specific kind of activity.

Following a contractual perspective, a key aspect is represented by the intangible nature of the relevant assets.[5] In addition to their degree of specificity – on which transaction cost economics focus – intangibles are more difficult to specify and verify in market transactions than tangible activities, and more exposed to hold-up problems. This could create inefficiencies that also reverberate on the firm's innovation capacity (Williamson, 1975; Gonzalez-Diaz et al., 2000). Conversely, and assuming their specificity is not high, the externalisation of tangible activities could enable the firm to save on internal costs, turn fixed costs into variable ones, and provide it with efficiency gains which are also exploitable in innovating.

Following an evolutionary perspective to outsourcing (Mahnke, 2001), an additional crucial aspect is represented by the core vs. non-core nature of the externalised activities.[6] Given their key-role, core resources and competencies are expected to contribute to the firm's innovation capacity providing they are managed internally (Windrum et al., 2009). Unless proper co-ordination mechanisms are set at work between the client and the provider,

---

[5] Intangibles are here meant as assets, in accounting terms, that unlike tangible ones (like machinery and plants, for example) are non-physical and thus non-touchable. Following the stream of research inaugurated by the seminal work by Corrado et al. (2005), and the standard taxonomy elaborated by NESTA within the "Innovation Index Project", we here refer to the following list of intangible activities of the firm: training, software development, company reputation and branding, Research and Development (R&D), design of products and services, organization or business process improvements.

[6] Core activities are represented by business functions, and by the inherent resources and competencies, that are strictly functional to the firm's strategy and thus critical for its success (Prahalad and Hamel, 1990).

outsourcing might entail the risk of losing the control of core competencies, of de-coupling them from other complementary activities, and of leaking sensitive information about them. Conversely, through the externalisation of non-core activities, the firm could reallocate the relative resources (e.g. labour) to more key-ones and make them more functional to strategic innovations.

Combining these two complementary perspectives, the standard argument for technological innovation is that a positive impact on it should accrue from the externalisation of all the activities but those for which short-run operative costs are too high and long term strategic aspects potentially compromised.[7] As the distinction between tangible and intangible assets apply invariably to standard innovations and eco-innovations like our EICO2, providing the sectors in which the outsourcing firms operate have also their core activities among the intangible ones, we expect that outsourcing might hinder the firm's capacity of EICO2 in normal conditions (e.g. with no adequate extra coordination mechanisms). For other less core intangible (e.g. cleaning and maintenance) and tangible activities (e.g. intermediate products), we instead expect a positive correlation could emerge in normal conditions (i.e. with low asset specificity). In brief, our second hypothesis reads like:

HP2: *EICO2 should benefit from (are hampered by) outsourcing tangible (intangible) activities.*

3. Empirical application

[7] As Arnold (2000) argues, the two criteria overlap only partially and the two metrics should thus be used complementary to define the firm's boundaries for the sake of innovation.

As a first test of our hypotheses, we refer to a research setting, in which our two focal variables – EICO2 and outsourcing – are more relevant and directly related than elsewhere, that is: "green industries" in "regional contexts". With the first term, we generically refer to firms whose main economic activity consists of the production of commodities and/or goods with a direct functional impact on the environmental sustainability of their customers and/or clients.[8] In a similar kind of green industries, the reduction of CO2 emissions, as well as of other environmental impacts, should be more frequently found among the objectives of the firms' innovating activities: either because it is required by their same business objective and production activities, or because it is prized by their sustainability-sensitive customers (explicitly or implicitly, that is in terms of reputation).

The "regional context" of our research setting is represented by a geographical context marked by those local phenomena – such firms' co-location, social embeddedness, network (rather than scale) economies, and the like – to which regional studies usually refer. In these settings, outsourcing is usually a means through which the relevant firms realise a local kind of labour division, which has been found to spur their interactive learning and technological outcomes (Capasso et al., 2013; Antonioli et al., 2014), and which we expect could do the same with respect to our EICO2. More precisely, we focus on four administrative regions (NUTS 2) of the North–East of Italy: Emilia Romagna, Friuli Venezia Giulia, Trentino Alto Adige and Veneto. These regions constitute one of the most dynamic areas in the country,

[8] The typical case, and indeed that of our empirical application too, is represented by firms involved in the production of materials and intermediate commodities to be used in building up "environmentally–friendly" houses – more in general, sustainable building – or to supply alternative forms of energy – such as, for example, photovoltaics.

with levels and rates of growth of GDP above the national average, where agglomeration economies in the form of industrial districts have flourished since the period immediately after the Second World War (Brusco, 1982; Becattini, 2002). The focus on this group of regions is suitable to test our research hypotheses for three reasons. First, the area is characterized by a flexible specialisation system with a widespread presence of SMEs, where outsourcing of production stages is the norm (Brusco, 1982). Second, the area is characterized by the active integration of communities of people and populations of industrial firms, which make of social capital an important deterrent to opportunistic behaviours in market transactions like outsourcing (Putnam et al., 1994). Third, in spite of the homogeneity of their production structure, the environmental performances of the four regions are quite differentiated.[9] This enables us to test the "green" impact of outsourcing in general for firms that, while operating in ecological sectors, are embedded in different economic and institutional settings.

In these four regions, we concentrate on two green sectors: sustainable building and photovoltaic industries. Sustainable building (also known as green construction) expands and complements the classical concerns of construction industry relative to economy, utility, durability, and comfort of buildings. In particular, sustainable building concentrates on structures and processes that are environmentally responsible and resource–efficient

---

[9] Just to give an example, Trentino-Alto-Adige has an outstanding record in the country in terms of green gas house emissions (GHG) per valued added (VA) (0.184 in 2005), Veneto and Emilia-Romagna holds the 10th (GH G/V A = 0.319) and 11th (GH G/V A = 0.345) positions, respectively, while Friuli Venezia Giulia is even lower in the ranking of the 20 regions (GH G/V AS = 0.407). See ISTAT, "Statistiche Ambientali" at http://www3.istat.it/dati/catalogo/200911300 0/.

throughout the building's life–cycle: siting, design, construction, maintenance, renovation, and demolition (Anink et al., 1996). The photovoltaic industry instead belongs to the second–generation technologies of the renewable energy industry. It mainly consists of the production of solar cells converting light into electricity. Photovoltaics industry in Italy has undergone an impressive process of growth: in the 2007-2012 period, solar photovoltaic installations and capacity growth rates are respectively 123% and 185% (GSE, 2012).

The relative importance of these two industries from an ecological point of view can be gauged by the share of employment pertaining to "green" occupations within them. Although not available for the Statistical classification of economic activities in the European Community (NACE), the Bureau of Labor and Statistics provides the green goods and services private sector employment for the corresponding classes in the 2012 North American Classification System (NAICS).[10] We build a cross-walk between the two industrial classifications (from the four digit NAICS 2012 to the two digit NACE rev. 2 industrial classifications) and compute the share of total employment due to "green" occupations for the two relevant classes and compare it to the average share of employment for the overall manufacturing industry. While the overall manufacturing sector is characterised by a share of employment "green" in the order of 4.3%, sustainable building and photovoltaics have a share of 9% and 7.9% respectively.[11]

---

[10] Available at http://www.bls.gov/green/.

[11] Further details on the analysis carried out to gauge the "green" weight of the two industries are available from the authors upon request.

3.1. Data

The sample used in this paper was extracted from an original database developed in 2011 by the joint effort of the Departments of Economics of the Universities of Bologna and Trento (Italy) within the OPENLOC research project (http://openloc.unitn.it/) A survey was launched to collect information on the regional industries described in Section 3, by administering between October and December 2010 a structured questionnaire through a telephone interview to the owners–managers. The questions concerned information on firms' structural characteristics — like age and employees — on a number of dimensions of their production and innovation processes (technological and non–technological), and on the relative outcomes.

Given the absence of a clear-cut industrial classification for sustainable building and photovoltaic industries, the firms' population has been identified by using different sources, in particular: (i) the registers of Italian chambers of commerce (CCIAA): (ii) the online Bureau Van Djik AIDA database: (iii) lists of participants to professional "green" exhibitions (Legno e Edilizia in Verona (17-20 March 2011), Ecocasa Expo in Reggio Emilia (3-6 March 2011), Impianti solari Expo in Parma (25-27 March 2011)) and (iv) a list of firms registered in industrial "green" associations (GIFI, ISES, APER, Habitech and GBC). The resulting population included 931 companies. From it, a subset of 213 target firms was extracted. This subset was stratified according to the administrative region (the second level in the Nomenclature of Territorial Units for Statistics codes) of firm location and industry segment (mainly 16 and 27 NACE rev. 2 codes).

Full information was finally obtained for 182 out of these 213 firms. This final sample is representative of the overall population of the 931 companies by region and industry segment ($\chi^2[3] = 0.07$ and $\chi^2[1] = 0.2$, respectively). We combined the information from the survey with data from three other sources. First, we retrieved Italian National Statistical Office (ISTAT) data for employment at the province–industry level (NUTS3 and NACE rev. 2, respectively). Again from ISTAT we used national accounting sector data (National Accounting Matrix with Environmental Account, NAMEA) to gather information on greenhouse gases (GHGs) and value added (VA) at the industry level (NACE rev. 2). We finally complement the information on the number of employees at the company level relying on data from Bureau van Dijk's database AIDA. We also geo-referenced the 931 firms comprising our population of interest and we built a spatial proximity variable.

With respect to the final sample of 182 companies, three sets of information are available for the period 2006-2010. First, information on their performance in terms of EIs, with a disaggregation of their typologies (e.g. pollution reducing vs. energy saving). Second, information on specific aspects of vertical organisation of firms' production — namely, their outsourcing decisions in the different activities of their value chain (e.g. cleaning services vs. human resource management). Finally, the database includes further information to control for relevant determinants of EICO2 (e.g. green R&D, motivations to carry out EI), as well as for their structural characteristics (e.g. size, age, etc.).

3.2. Econometric model and dependent variables

The dependent variable of our empirical exercise is the introduction of new (or significantly improved) environmental innovation aimed at reducing CO2 emissions (EICO2). Respondents were asked CIS–like questions, addressing a set of different environmental benefits coming from product, process, service, organisational and marketing innovations. Following the Community Innovation Survey (CIS) 2006-2008, which for the first time comprehends a special environmental session, firms were asked whether the company introduced an innovation able to reduce CO2 'footprint' (total CO2 production).

Operationally, we define EICO2 as a dummy variable equal to 1 if the firm introduced and environmental innovation for CO2 abatement during the 2006-2010 period, and 0 otherwise.

The relationship between outsourcing and EICO2 is then investigated by means of the following baseline logit model:

$$P(Y_i = 1|X_i, Z_i, V_j) = \Lambda(\beta_i X_i + \delta Z_i + \zeta V_j)$$

where $\Lambda(\mathrm{z}) = (e^z/(1 + e^z)$ is the logistic function. Y_i is the measure of environmental innovation performance presented above (i.e., EICO2), X_i is a vector of variables including measures of outsourcing activities carried out by firm i in the 2006-2010 period (see Section 3.3); Z_i and V_j indicate a series of firm– and industry–specific control variables.

We then provide several robustness checks. First, we re–estimate the model to control for endogeneity and for sample selection issues. As for the former, unobserved covariates may be simultaneously correlated with EICO2 and our outsourcing variables thus biasing our coefficients. We take into account this problem by instrumenting for the outsourcing variables (in particular, of tangibles and intangibles) with a set of exogenous variables (see

Section 4.3.1 for further details). As for the latter, we control for the possibility of self-selection in terms of the group of companies undertaking green R&D (see Section 4.3.2 for further details). If this element of selectivity is significant, estimation of our model might lead to biased results (Love and Roper, 2002; Piga and Vivarelli, 2004). We take into account the above issue by estimating a probit model with sample selection (Van de Ven and Van Praag, 1981).

Second, in order to better control whether our results are driven by the adoption of the specific kind of CO2-reducing eco-innovations at stake, we re-estimate our baseline model using different definitions of environmental innovations. Following the extant literature (e.g. Ghisetti et al., 2014; Horbach et al., 2013), we refer to three alternatives. First, we define *Eco–innovation (Overall)* as a dummy taking value 1 when the company has introduced/adopted at least one of the following 8 typologies of environmental innovation: (i) reduced material use per unit of output; (ii) reduced energy use per unit of output; (iii) reduced CO2 'footprint' (total CO2 production); (iv) replaced materials with less polluting or hazardous substitutes; (v) recycled waste, water, or materials; (vi) reduced energy use; (vii) reduced air, water, soil or noise pollution; (viii) improved recycling of product after use.

The other two alternatives are obtained by looking at their specific descriptions, and distinguishing among the 8 typologies those that can be treated as product rather than process EIs. With the dummy *Eco–innovation (Product)*, we identify whether the firm has obtained environmental benefits that can be referred to the after–sales use of its goods or services, that is EIs from (vi) to (viii). On the same token, we create the variable *Eco–innovation (Process)*, which takes value 1 if the firm has introduced innovations with environmental benefits during the production of goods or services, that is EIs from (i) to (v), and 0 otherwise.

3.3. Independent and control variables

Our main independent variables are the firm's outsourcing decisions with respect to the 17 different activities that the OPENLOC survey distinguishes. Our first measure refers to the firm's overall reliance on outsourcing. *Outsourcing* takes on value 1 whether the firm has carried out any type of outsourcing activity in the period 2006-2010 and 0 otherwise.[12] The remaining two measures of outsourcing are obtained by grouping the 17 activities into two classes: outsourcing of either tangible or intangible activities. The first one, *Outsourcing tangibles*, is a dummy variable taking value 1 if the firm outsourced any of the following activities: inventories management, internal logistics, distribution logistics, cleaning services, plants maintenance, machinery maintenance, data processing, supply of intermediate products, production stages and other production activities. The second outsourcing variable, *Outsourcing intangibles*, is a dummy, taking value 1 if the firm outsources any of the following activities: marketing, research & development, project design, human resource management, information systems, enterprise resource planning, quality control, development of IPRs, and 0 otherwise.

As can be immediately appreciated, these two groups of activities are likely to contribute differently to the firm's innovation potential and value added and their externalisation can

[12] In order to test for different degrees of vertical disintegration, we have also constructed a count variable based on the number of outsourcing activities carried out by the firms. As the results do not change, we have omitted this empirical test for the sake of clarity, although results are available upon request.

thus be expected to have a different impact on its capabilities of innovating, and of reducing CO_2 emissions in particular. This is somehow confirmed by the extent to which the sample firms have resorted to outsourcing for the three groups (Table 1). Table 1 shows the proportion of companies carrying out outsourcing of tangible activities for the group of firms introducing CO_2 eco–innovation against those that do not (26.67% vs 13.87%, with the difference being significant at the 10%). Quite interestingly, no significant difference is found for outsourcing in general and outsourcing of intangible activities (28.89% vs 19.71% and 13.33% vs 13.14% respectively). Overall, this descriptive evidence points to a different relationship between different types of outsourcing activities and eco-innovative potential.

A set of other variables refers to the environmental factors that are most likely to influence CO_2 abatement. First, we control whether the firm has expenditures for R&D related to environmental protection in the 2006-2010 period. *Green R&D* is a dummy taking value 1 whether the firm has invested resources with the specific aim to reduce its environmental impact and 0 otherwise. Second, we control for overall regulation stringency at the industry level. Assuming that, in line with other works in the field (Cainelli et al., 2012), the higher the overall regulation stringency to which a firm is associated, the higher its environmental efficiency, as an indirect proxy of the former we compute the (naturally log transformed) ratio between greenhouse gases (GHGs) and value added (VA) at industry level (*Log GHG/VA*) in 2009. We also include a dummy, *Internal procedures*, taking on value 1 whether the firm have internal procedures in place to regularly identify and reduce its environmental impacts (e.g. ISO 14001 certification, environmental audits, etc.) and 0 otherwise (Angel and Rock, 2005). Lastly, we include a set of five dummy variables to control for the motivation to carry out environmental innovations. The motivation dummies are defined distinguishing among the following set of reasons that may have influenced the decision to eco–innovate: existing environmental regulations or taxes on pollution (*Existing regulations*); expected regulations or taxes (*Expected regulations*); availability of government grants, subsidies or other financial incentives (*Financial incentives*); current or expected market demand from customers (*Current or expected market demand*) and voluntary codes or agreements for environmental good practice (*Good practice*).

In order to take into account the specific geographical context of our application, we have included a variable (*Log Spatial Proximity*), which refer to the natural logarithm (plus one) of the average geographical distance (in km) of firm *i* from the other 930 companies identified as the population.[13] Given the pervasive presence of industrial districts in the North–East of Italy, we take this geographical proximity as a first kind of evidence of the Marshallian economies that characterise them. We also control specific regulations enacted at the regional administrative level by including a set of four geographical dummy variables defined for the four administrative regions (*Emilia Romagna*, *Friuli Venezia Giulia*, *Trentino Alto Adige and Veneto*).

In addition, we have included a number of controls on firm's structural characteristics. First, a variable related to firm size measured as the natural logarithm of the number of employees (plus one) in the 2006-2010 period (*Log Employees*) is inserted. We also included a variable representing the international orientation of the firm (*Log Share Export Sales*), defined as the

[13] As mentioned in Section 3.1 all companies from the population were appropriately geo-referenced. Thus, for each of the 182 firms contained in our sample we have been able to compute the average geographical distance from the remaining 929 (i.e. 930 minus the focal company) companies in the population.

(natural) logarithm of the shares of exports in sales (plus one) in the 2006-2010 period. *Log Age* represents the (natural) logarithm of firm age (plus one) in 2010. *Group* is a dummy variable that takes value 1 whether the firm is part of a group of firms and 0 otherwise.

Table 2 provides the descriptive statistics of the variables defined above. Table 3 reports the correlation matrix for the main variables considered in the analysis and shows that the bivariate correlations among our main variables are generally weak. There is no indication of significant multi–collinearity amongst the independent variables (i.e. the Variance Inflation Factor ranges from 1.11 to 2.6, well below the accepted threshold level of 5).

4. Results

4.1. Outsourcing and EICO2

The first set of results that we present refers to firm's outsourcing in general, that is, to a reduction in its vertical scope induced by the externalisation of any of its economic activities. Before commenting on these results, it is worthwhile noticing that, while the actual location of the provider is not known from the dataset, this general outsourcing can be deemed mainly domestic and only limitedly accounted by offshoring operations. In fact, the degree of internationalisation of the sample firms is quite low, as only 4.95% of them have foreign equity participation and just 3.85% of firms have conducted FDI in the period 2006–2010. Moreover, the largest proportion of these FDI has been carried out within the EU15 area (55% of cases), with respect to which international asymmetries in environmental regulations are relatively low (than extra EU). On this basis, we feel confident that our empirical application actually refers to a context where outsourcing is a mean for a local kind of labour division, rather than for searching more tolerant CO2 and environmental locations abroad, as from the Pollution Haven Hypothesis (see footnote 1).

Going back to our results (Table 4), column 1 shows that the probability of introducing an eco–innovation with a CO2 impact is positively related to the firm's carrying out R&D for eco-innovative projects, that is 'green R&D'. This confirms the specific nature of the innovation at stake, for which a general involvement in the exploration and exploitation of new knowledge (i.e. R&D in general) does not seem to be enough, unless targeted to solve problems in a dedicated green realm. Quite interestingly, a significant and positive correlation also emerges for the international orientation of the company, as accounted for by the export share of its sales. This is consistent with what emerges from other studies on the need that local firms have to stick with more numerous and stringent environmental regulations on CO2 when playing on the global markets, and on the need to have an environmental reputation to compete on them (Cainelli et al., 2012). A higher degree of vertical disintegration of the sample firms is instead not significant in accounting for their EICO2. Apparently, the first hypothesis we put forward by looking at the kind (radical vs. incremental) of innovation EICO2 represents (Section 2.1) is not supported. However, the argument we developed about the role that a Schumpeter Mark II regime could have in attenuating the validity of this hypothesis (Section 2.2) can be apparently confirmed. In the two industries at stake, as well as in other green ones, the sectorial system of innovation enriches of a new element with respect to the standard ones, which interacts with the underlying technological regime and affects its dynamics: environmental and innovation policy (Oltra and Saint Jean, 2009). The need/will of complying with the extant regulation tends to stimulate firms in these sectors to improve their environmental performances by sticking to a viable dominant design and innovating gradually around it. In other words, the "regulatory push/pull effect" in green sectors, and in eco-innovating in general, tends to create situations of path-dependence and of technology inertia that are typical of a Schumpeter Mark II regime.[14] Finally, consistent with a green routinised regime is also the emerging evidence of highly concentrated patterns of inventive activities in green technologies using patent data (Liston-Heyes and Pilkington, 2004).

All in all, considering the specific technological regimes that the two sectors of our application embody, a non-significant correlation between EICO2 and outsourcing in general is not completely unexpected.

4.2. Tangibles vs. intangibles outsourcing and EICO2

In column 2 of Table 4, the probability to introduce an EICO2 turns out to be significantly related to outsourcing, once this latter variable is split into its tangible and intangible components. Indeed, both variables are statistically significant and, in true accordance with our theoretical framework, they have radically different effects. Outsourcing of tangible assets has a positive correlation with EICO2, while that of intangible ones has a negative sign.

---

[14] Oltra and Saint Jean (2009) develops this argument with respect to the case of low emission vehicles in the automotive industry, but the same logic for us applies even more to EICO2 in green industries.

Our second hypothesis (HP2) is thus confirmed. While the propensity to innovate and reduce the CO2 footprint is higher for those firms that have externalised some of their tangibles, not only does the externalisation of intangibles hamper EICO2, but it even makes it less possible. This last result finds a consistent explanation in the role that intangible assets have in the two industries we are considering. Not only are intangibles affected by higher contractability problems than tangibles, as it could be elsewhere according to standard transaction costs arguments. Following a resource-based perspective, their externalisation could be also strategically problematic, involving a potential loss of control on core activities and knowledge that, also and above all in green sectors are to be found in the firm's intangibles. This is for sure the case of R&D, which is deemed core in complementing the basic research and public technology programs on which CO2 emissions still largely depend (Horbach et al., 2012, p. 117). Information technologies (IT) are another group of sensible activities, whose impact on both energy efficiency and carbon footprint have been largely debated (e.g. Faucheux and Nicolai, 2011). Organizational monitoring and quality-control activities, which can comprehend those for the "environmental quality" of the firm (such as ISO schemes, EMAS and other environmental management systems), have also been argued to complement EICO2 and EI in general (Cainelli et al., 2012). In sectors other than green-ones, EICO2 has emerged as the only case of EI whose adoption can be fostered by the joint implementation of work practices and Human Resource Management (Antonioli et al., 2013), making them relevant for their outsourcing analysis. Last, but not least, sensible in the same respect are marketing, design and related (e.g. trademarks) activities, given their role in conveying to the eco-innovating firm the pulling action of the market (Veryzer, 2005; Horbach et al., 2012).

Overall, our second research hypothesis about an "EICO2–friendly" and an "EICO2–hostile" use of outsourcing of tangibles and intangibles, respectively, seems to be confirmed. The externalisation of the activities with a fairly controllable and prone to cost–saving/efficiency–gain has a positive impact. However, the decision to externalise intangible has a negative one. This could be caused by problems of hold–up (following the TCE logic) and/or, following a competence perspective, by the loss of control on resources that are pivotal for the firm's EI. This seems to suggest that with respect to EICO2, the microeconomic problems associated to outsourcing are still more relevant than their meso-economic, namely, spatial implications. Somehow confirmative in this respect is the fact that the proximity variable, which we introduced to account for the role that agglomeration economies are usually found with respect to standard innovations, is not significant with respect to EICO2.

4.3. Robustness checks

Endogeneity

A major concern with the model we estimate is that there may be a potential endogeneity problem, i.e. there may be unobserved covariates simultaneously correlated with EICO2 and our outsourcing variables that may be biasing our coefficients. For example, it might be the case that highly innovative companies are more skill intensive and therefore more likely to use outsourcing to shift the production of low-skill-intensive components outside the firm (Girma and Gorg, 2004; Gorg et al., 2008). Similarly, highly innovative companies might be better embedded into networks of R&D alliances and, for this reason, more likely to resort to outsourcing of intangibles (Gorg and Hanley, 2011).

We take into account these problems by instrumenting for the two outsourcing variables that appear significant: for outsourcing of tangibles we use the lagged value of firm size, the extent of unionisation, and the level of social capital; for outsourcing of intangibles we use the importance of production and knowledge relationships.

As for the former, we refer to the literature on the determinants of outsourcing decisions (Abraham and Taylor, 1996), and focus on a set of drivers of it, for which an EICO2 impact can be excluded. First of all, we postulate a positive relationship between lagged firm size and outsourcing of tangibles. This is in line with the argument that larger companies may rely more on outsourcing because they are more efficient in subdividing their value chain, having a larger scale, and in exploiting international value chains (Mazzanti et al., 2009). On the other hand, we expect a negative relationship between the extent of unionisation in an area and the outsourcing of tangibles by its firms, being the former usually associated to higher wage costs and higher incentives to externalise for saving on labour costs (Mazzanti et al., 2009) Similarly, a higher level of social capital is assumed to reduce opportunistic behaviours and rent-seeking in market transactions, and allows a higher resort to outsourcing among firms (Burker and Minerva, 2013). Specifically, we define *Pre-det Size* as the turnover of the firm in the pre-sample year 2005. We further define *Unionisation* at the province level as the ratio between the number of registered workers to the two most important unions in Italy (CGIL and CISL) and the total number of employed workforce in 2005. Finally, we proxy for social capital by using the number of employees in social enterprises over the total in 2005 (*Social Cap*).

To construct the exclusion restrictions for our variable on the outsourcing of intangibles we instead resort to our survey and look at the presence of activities through which the sample firms have carried out coordinated exchanges of knowledge transfer and of innovation cooperation. While we exclude that the underlying relationships could directly impact on the decrease of the CO2-footprint of the focal firms, we retain them as important sources of experience and competencies in identifying and dealing with the problems that the externalisation of intangibles entail (Montresor and Vezzani, 2014). More precisely, we defined *Knowledge rel* as a dummy variable taking value 1 if the firm answered yes to the following question: "Has your company conducted activities designed to acquire new knowledge from other companies in the period 2006–2010?" and 0 otherwise. Similarly, we defined the variable *Product rel* as a dummy taking value 1 if the firm answered yes to the following question: "During the period 2006-2010, has your company established collaboration activities aimed at the creation of a new product or service?" and 0 otherwise.

We report two different specifications of our IV model. In our first specification we use a two-step efficient generalized method of moments (GMM) estimator. Compared to the standard two-stage least square IV estimator the GMM estimator generates efficient estimates of the coefficients as well as consistent estimates of the standard errors (Hayashi, 2000; Baum et al., 2007). As a second specification we use a limited–information maximum likelihood estimator (LIML). LIML has the advantage of reporting estimates that are more robust to the weak instrument problem.

We are also careful to run a battery of appropriate statistical tests for our model. First, we check whether endogeneity is really an issue in our case by running an endogeneity test robust to heteroschedasticity. Second, we test the validity of the chosen instrumental variables via a Sargan-Hansen test of overidentifying restrictions. Finally, as a weak correlation between the instruments and the endogenous variable(s) produces biased estimates for instrumental-variables regression (Staiger and Stock, 1997), we cope with the issue of weak instruments in two ways. We first check whether our instruments are affected by a weak instrument problem by running the Kleinbergen & Paap statistical test (Baum et al., 2007). We then adopt a LIML estimator that has been proven to produce estimates robust to the problem of weak instrument(s) (Chao and Swanson, 2005).

Table 5 presents the empirical estimates with first-stages (columns 1 and 2) and the final IV estimates (columns 3 and 4).[15] First of all, it must be noted that our main explanatory variables are affected by a problem of endogeneity. The endogeneity test rejects the null hypothesis of exogenous regressors at the 5% significant level. Overall, the results from the instrumental variable regressions confirm the main results obtained in Table 4. Indeed, column 3 in Table 5 shows a positive coefficient of *Outsourcing Tang* and a negative coefficient of *Outsourcing Intang* (both significant at the 5% confidence level).

Our results are quite robust to the weak instrument problem. First of all, the chosen instruments are correlated with the endogenous regressors to a good extent. This is apparent from the results of the first stage equations. *Pre-det Size* (*Unionisation*) is positively (negatively) related to the outsourcing of tangibles while *Knowledge rel* and *Product rel* are both positively associated to the outsourcing of intangibles. The coefficient for social capital

[15] *Pre-det size* has missing values for 66 companies thus reducing the number of observations to 116 compared to other estimates.

(*Social cap*) is not significant at the standard confidence levels.[16] It is also apparent that instruments behave as anticipated in our theoretical argumentation in the previous paragraph — i.e. firm size, the degree of unionisation and social capital (to a lesser extent) correlate with the outsourcing of tangibles while knowledge and product relationships influence the outsourcing of intangibles. At the bottom of Table 5 we report the weak identification test from Baum et al. (2007). This test reports a value slightly below the critical value of 5.91 meaning that the two–step GMM estimator might be affected by a problem of weak instruments. In order to rule out any bias in our results, we estimate an IV model via the LIML estimator (column 4 Table 5) that is more robust to weak instruments. Our main results are unaffected by this new estimator and this time the weak identification test is below the critical value of 2.78 (Baum et al., 2007). Finally, we check the validity of our instruments by reporting the value for the Sargan–Hansen J test of over-identifying restrictions. The test does not reject the null hypothesis of instruments validity, thus supporting our claim that the chosen instruments are uncorrelated with the error term.

Sample selection

A further issue that may arise from our estimates refer to the possibility for a group of firms conducting outsourcing of intangibles to select themselves in the group of companies undertaking green R&D. As highlighted by an extensive body of literature (Veugelers, 1997;

[16] The coefficient for *Knowledge rel* is positive and significant for both the outsourcing of tangibles and intangibles but they are statistically different (at the 10%).

Veugelers and Cassiman, 1999), it is reasonable to expect a certain degree of complementarity between the probability to contract–out intangible activities (of which R&D is an integral part) and the probability to conduct green R&D activities internally. If the probability to outsource intangibles is strongly correlated with *Green R&D*, the estimates we obtain for the relationship between *Outsourcing of intangibles* and EICO2 might be actually biased by a self-selection problem. It is therefore necessary to allow explicitly for the possibility of some selection bias in the estimation of the EICO2 equation (Maddala, 1983).

Given the dichotomous nature of our dependent variable we resort to a probit model with sample selection (Van de Ven and Van Praag, 1981). The selection equation regresses *Green R&D* against a subset of the explanatory variables used in our main model that are more likely to impact on internal green R&D activities (refer to Section 3.3): firm size (*Log Employees*), internal procedures in place to regularly identify and reduce firm environmental impacts (*Internal procedures*), outsourcing of tangibles and intangibles (*Outsourcing Tang* and *Outsourcing Intang*) and a set of geographical controls. The model also specifies one exclusion restriction in the form of a dummy equalling 1 whether the firm has acquired new knowledge from public research centres in the period 2006-2010 (*Knowledge rel Uni*). Such a restriction is consistent with theoretically supported evidence on the pivotal content of basic, academically related research in the R&D activities for green innovation projects in general, and by that of the applied nature of the knowledge through which EICO2 take form (Rennings et al., 2013).

Table 6 presents the empirical estimates for the sample selection model. Selection equation (column 1) shows a positive correlation (at the 10% level of significance) between *Outsourcing of intangibles* and *green R&D* supporting the claim that firms carrying out outsourcing of intangibles are more likely to conduct internal green R&D. This confirms our expectations on the complementarity between external and internal R&D activities as found by the extant literature (Veugelers, 1997; Veugelers and Cassiman, 1999). More importantly, our exclusion restriction is positively related to *green R&D*. Indeed, *Knowledge rel Uni* exerts a positive (and significant) influence on *green R&D*. Column 2 of Table 6 reports the outcome equation and confirms our main results of a positive (negative) and significant association between *Outsourcing of tangibles* (*intangibles*) and CO2 eco–innovation. Quite interestingly, the Wald test on the independence of the two equations is not rejected at the standard statistical levels ($\chi^2(1) = 0.31$) pointing to a mild problem of selection bias in our estimates.

Other types of eco–innovation activities

As a final robustness check, we aim at testing whether the results obtained for EICO2 hold when other kinds of eco-innovations (EI) are considered, or if instead they are specific to the kind of environmental impact we are taking into account. As we said, we refer to three alternatives, represented by the firm's involvement in any kind of EI, product EI, and process EI (as defined in Section 3.3).

Table 7 shows that, in all the three cases, outsourcing of both tangible and intangible assets confirm its double impact (negative for intangibles and positive for tangibles). This suggests that the main result that we obtained with respect to EICO2 could be a general one in terms of eco-innovation, in green sectors at least, and thus worthwhile investigating more systematically in future research. On the other hand, some interesting changes emerge across the three models of Table 7. In the case of product eco–innovation (column 2 of table 7) being part of an industrial group has a negative and significant impact on the probability of producing an eco–innovation. This fact is linked to the more strategic nature of the innovative process within industrial groups, which can decide to produce innovation in one of the various centres constituting the group based on strategic rather that purely capability reasons. The regulatory stringency has a negative and significant impact on product EICO2 (and also on overall EICO2), pointing to a possible trade-off between regulatory efficiency and innovative behaviour. Also the sales export share is positively linked to the probability to eco-innovate.

A rather different picture emerges if the process eco–innovation is considered. In this case, besides the outsourcing co–variates, the only control that turns out to be significant, is the export share of sales. This could be meant as a (weak) evidence of a more demand–led type of innovative activity.

Finally, if we evaluate (Table 8) the impact in terms of the percentage change in the probability to conduct different types of eco–innovation (overall, product and process), we obtain that the impacts vary widely. In particular, the biggest positive impact of the outsourcing of tangible assets is on overall eco–innovation (a change from zero to one implies an increase of 28.6%), while the smaller impact in on product eco–innovation (in this case the same variation in the dummy variables implies an increase of 20.9%). As for the intangibles, the impact of a change in the dummy variable from zero to one implies a decrease of 13.3% in EICO2, while for process and overall eco–innovation is around 26%. This seems to further confirm our results as the impact of both tangibles and intangibles is higher on process eco– innovation rather than product ones. Moreover, tangibles seem to have the higher impact on overall eco–innovation, while intangibles seems to have the smaller negative impact on EICO2.

5. Concluding remarks

In this paper we empirically evaluated the relationship between different forms of outsourcing and eco–innovation activities of a set of Italian firms active in two green sectors. To our knowledge these types of analysis (that are relatively common in the literature on innovation) is the first attempt to do so in green sectors. Moreover, our dataset allowed us to distinguish different types of eco-innovative activities and of outsourcing.

Even when PHH is not taken into account, and only eco–sustainable sectors are considered, outsourcing does not appear to have a fully supportive role in spurring environmental innovation. On the contrary, the externalisation of activities that can be deemed core for the adoption of EIs even decrease the firm’s propensity to eco–innovate. Our main results highlight the importance of differences in the types of eco–innovation that is retained as the focus of the analysis, since eco–innovation are complex objects whose nature is mixed and that can easily shift their focus from a purely material to an immaterial production process, or that can be limited to some simple components or span to system level.

Our results show that the role of outsourcing of tangible assets is crucial in eco–innovative performance of our set of firms, and that outsourcing of intangibles is detrimental to the process of eco–innovation, although less in the case of the innovation upon which we have focused our empirical analysis (i.e. EICO2). This must be strictly connected to the idiosyncratic nature of these green sectors, for which the R&D to consider is not the whole expenditure as is usually done, but that focused on particular (green) products and processes. Overall, our results are extremely robust in econometric terms, and point to some interesting environmental implications of the standard “make–or–buy” issue in industrial organisation.

References

Abraham, K. G. and S. K. Taylor (1996). Firms' use of outside contractors: Theory and evidence. *Journal of Labor Economics* 14 (3), 394–424.

Ambec, S., M. A. Cohen, S. Elgie, and P. Lanoie (2013). The Porter hypothesis at 20: can environmental regulation enhance innovation and competitiveness? *Review of Environmental Economics and Policy* , 7(1): 2-22.

Angel, D. P., & Rock, M. T. (2005). Global standards and the environmental performance of industry. *Environment and Planning A*, 37(11), 1903.

Anink, D., C. Boonstra, and J. Mak (1996). *Handbook of Sustainable Building: An Environmental Preference Method for Selection of Materials for Use in Construction and Refurbishment*. London: James & James.

Antonioli, D., S. Mancinelli, and M. Mazzanti (2013). Is environmental innovation embedded within high-performance organisational changes? The role of human resource management and complementarity in green business strategies. *Research Policy* 42 (4), 975–988.

Antonioli, D., M. Mazzanti, S. Montresor, and P. Pini (2014). Outsourcing and firm productivity in a specific local production system. Evidence from Reggio Emilia (Italy). *Growth & Change* (forthcoming).

Arnold, U. (2000). New dimensions of outsourcing: a combination of transaction cost economics and the core competencies concept. *European Journal of Purchasing & Supply Management* 6 (1), 23–29.

Baum, C. F., M. E. Schaffer, and S. Stillman (2007). Enhanced routines for instrumental variables/gmm estimation and testing. *Stata Journal* 7 (4), 465–506.

Becattini, G. (2002). From Marshall to the Italian Industrial Districts. A Brief Critical Reconstruction. In *Complexity and Industrial Clusters*, pp. 83–106. Springer.

Breschi, S., F. Malerba, and L. Orsenigo (2000). Technological regimes and Schumpeterian patterns of innovation. *The Economic Journal* 110 (463), 388–410.

Brezet, H. (1997). Dynamics in ecodesign practice. *Industry and Environment* (20), 21–24.

Brunnermeier, S. B. and A. Levinson (2004). Examining the evidence on environmental regulations and industry location. *The Journal of Environment & Development* 13 (1), 6–41.

Brusco, S. (1982). The Emilian model: productive decentralisation and social integration. *Cambridge Journal of Economics* 6 (2), 167–184.

Burker, M. and G. A. Minerva (2013). Civic capital and the size distribution of plants: Short-run dynamics and long-run equilibrium. *Journal of Economic Geography* , lbt032.

Cainelli, G., M. Mazzanti, and S. Montresor (2012). Environmental innovations, local networks and internationalization. *Industry and Innovation* 19 (8), 697–734.

Capasso, M., L. Cusmano, and A. Morrison (2013). The determinants of outsourcing and offshoring strategies in industrial districts: evidence from Italy. *Regional Studies* 47 (4), 465–479.

Carrillo-Hermosilla, J., P. Del Rio, and T. Konnol (2010). Diversity of eco-innovations: Reflections from selected case studies. *Journal of Cleaner Production* 18 (10), 1073–1083.

Chao, J. C. and N. R. Swanson (2005). Consistent estimation with a large number of weak instruments. *Econometrica* 73 (5), 1673–1692.

Corrado, C., C. Hulten, and D. Sichel (2005). Measuring capital and technology: an expanded framework. In *Measuring Capital in the New Economy*, pp. 11–46. University of Chicago Press.

Del R´ıo Gonz´alez, P. (2009). The empirical analysis of the determinants for environmental technological change: A research agenda. *Ecological Economics* 68 (3), 861–878.

Ehrenfeld, J. (2001). Designing 'sustainable' product/service systems. Proceedings of the Second International Symposium on EcoDesign 2001 , 12–23.

Faucheux, S. and I. Nicola¨ı (2011). IT for green and green IT: A proposed typology of eco-innovation. *Ecological Economics* 70 (11), 2020–2027.

Frenken, K., M. Hekkert, and P. Godfroij (2004). R&d portfolios in environmentally friendly automotive propulsion: variety, competition and policy implications. *Technological Forecasting and Social Change* 71 (5), 485–507.

Ghisetti, C., A. Marzucchi, and S. Montresor (2014). Does external knowledge affect environmental innovations? An empirical investigation of eleven European countries. *Research Policy* (forthcoming).

Girma, S. and H. Gorg (2004). Outsourcing, foreign ownership, and productivity: Evidence from uk establishment-level data. *Review of International Economics* 12 (5), 817–832.

Gonzalez-Diaz, M., B. Arrunada, and A. Fernandez (2000). Causes of subcontracting: evidence from panel data on construction firms. *Journal of Economic Behavior & Organization* 42 (2), 167–187.

Gorg, H. and A. Hanley (2011). Services outsourcing and innovation: An empirical investigation. *Economic Inquiry* 49 (2), 321–333.

Gorg, H., A. Hanley, and E. Strobl (2008). Productivity effects of international outsourcing: evidence from plant-level data. *Canadian Journal of Economics* 41 (2), 670–688.

GSE (2012). Rapporto statistico 2012: Solare fotovoltaico. Technical report, Gestore Servizi Energetici (GSE). Available at http://tinyurl. com/cesvh9g.

Hayashi, F. (2000). *Econometrics*. Princeton University Press. Princeton.

Henderson, R. M. and K. B. Clark (1990). Architectural innovation: the re-configuration of existing product technologies and the failure of established firms. *Administrative Science Quarterly* , 9–30.

Holl, A. (2008). Production subcontracting and location. *Regional Science and Urban Economics* 38 (3), 299–309.

Horbach, J. (2008). Determinants of environmental innovation: New evidence from German panel data sources. *Research Policy* 37 (1), 163–173.

Horbach, J., V. Oltra, and J. Belin (2013). Determinants and specificities of eco-innovations compared to other innovationsan econometric analysis for the French and German industry based on the community innovation survey. *Industry and Innovation* 20 (6), 523–543.

Horbach, J., C. Rammer, and K. Rennings (2012). Determinants of ecoinnovations by type of environmental impact. The role of regulatory push/pull, technology push and market pull. *Ecological Economics* 78, 112–122.

Jeppesen, T., J. A. List, and H. Folmer (2002). Environmental regulations and new plant location decisions: Evidence from a meta-analysis. *Journal of Regional Science* 42 (1), 19–49.

Jiménez, O. (2005). Innovation-oriented environmental regulations: direct versus indirect regulations; an empirical analysis of small and medium-sized enterprises in Chile. *Environment and Planning A*, 37(4), 723-750.

Levinson, A. and M. S. Taylor (2008). Unmasking the pollution heaven effect. *International Economic Review* 49 (1), 223–254.

Liston-Heyes, C. and A. Pilkington (2004). Inventive concentration in the production of green technology: A comparative analysis of fuel cell patents. *Science and Public Policy* 31 (1), 15–25.

Love, J. H. and S. Roper (2002). Internal versus external R&D: a study of R&D choice with sample selection. *International Journal of the Economics of Business* 9 (2), 239–255.

Maddala, G. S. (1983). *Limited-dependent and qualitative variables in econometrics*. Cambridge university press.

Mahnke, V. (2001). The process of vertical dis-integration: an evolutionary perspective on outsourcing. *Journal of Management and Governance* 5 (3-4), 353–379.

Malerba, F. and L. Orsenigo (1995). Schumpeterian patterns of innovation. *Cambridge Journal of Economics* 19 (1), 47–65.

Marsili, O. (2002). Technological regimes and sources of entrepreneurship. *Small Business Economics* 19 (3), 217–231.

Mazzanti, M., S. Montresor, and P. Pini (2009). What drives (or hampers) outsourcing? evidence for a local production system in Emilia Romagna. *Industry and Innovation* 16 (3), 331–365.

McIvor, R. (2005). *The Outsourcing Process: Strategies for Evaluation and Management*. Cambridge: Cambridge University Press.

Montresor, S. and A. Vezzani (2014). Intangible investments and innovation propensity. Evidence from the Innobarometer 2013. Technical report, JRC- IPTS, European Commission.

Oltra, V. and M. Saint Jean (2009). Sectoral systems of environmental innovation: an application to the French automotive industry. *Technological Forecasting and Social Change* 76 (4), 567–583.

Picazo-Tadeo, A. J., & García-Reche, A. (2007). What makes environmental performance differ between firms? Empirical evidence from the Spanish tile industry. *Environment and Planning A*, 39(9), 2232.

Piga, C. A. and M. Vivarelli (2004). Internal and external R&D: A sample selection approach. *Oxford Bulletin of Economics and Statistics* 66 (4), 457–482.

Prahalad, C. and G. Hamel (1990). The core competence of the corporation. *Harvard Business Review* 68 (3), 79–91.

Putnam, R. D., R. Leonardi, and R. Y. Nanetti (1994). *Making Democracy Work: Civic Traditions in Modern Italy*. Princeton: Princeton University Press.

Rennings, K., P. Markewitz, and S. Vogele (2013). How clean is clean? incremental versus radical technological change in coal-fired power plants. *Journal of Evolutionary Economics* 23 (2), 331–355.

Robertson, P. L. and R. N. Langlois (1995). Innovation, networks, and vertical integration. *Research Policy* 24 (4), 543–562.

Staiger, D. and J. H. Stock (1997). Instrumental variables regression with weak instruments. *Econometrica* 65 (3), 557–586.

Van de Ven, W. P. and B. Van Praag (1981). The demand for deductibles in private health insurance: A probit model with sample selection. *Journal of econometrics* 17 (2), 229–252.

Veryzer, R. W. (2005). The roles of marketing and industrial design in discontinuous new product development. *Journal of Product Innovation Management* 22 (1), 22–41.

Veugelers, R. (1997). Internal r & d expenditures and external technology sourcing. *Research policy* 26 (3), 303–315.

Veugelers, R. and B. Cassiman (1999). Make and buy in innovation strategies: evidence from belgian manufacturing firms. *Research policy* 28 (1), 63–80.

Wagner, U. J. and C. D. Timmins (2009). Agglomeration effects in foreign direct investment and the pollution haven hypothesis. *Environmental and Resource Economics* 43 (2), 231–256.

WBCSD (2012). Measuring eco-efficiency: A guide to reporting company performace. Discussion paper, World Business Council for Sustainable Development.

Williamson, O. E. (1975). *Markets and Hierarchies*. New York: Free Press.

Windrum, P., A. Reinstaller, and C. Bull (2009). The outsourcing productivity paradox: total outsourcing, organisational innovation, and long run productivity growth. *Journal of Evolutionary Economics* 19 (2), 197–229.

Table 1: Proportion of companies having introduced EICO2 — outsourcing, outsourcing of tangibles and outsourcing of intangibles

	EICO2		**Fisher's exact test**
	Yes	***No***	***p-value***
Outsourcing	28.89	19.71	0.216
Outsourcing Tang	26.67	13.87	0.06*
Outsourcing Intang	13.33	13.14	1
Observations	45	137	

* $p < 0.1$. Fisher's exact test instead of the standard χ^2 test is reported as more robust to small sample size.

Table 2: Descriptive Statistics (n=182)

	Mean	Std. Dev.	Min	Max
Dependent variables				
EICO2	0.247	0.432	0	1
Eco–innovation (Overall)	0.34	0.475	0	1
Eco–innovation (Product)	0.318	0.467	0	1
Eco–innovation (Process)	0.335	0.473	0	1
Explanatory variables				
Outsourcing	0.219	0.415	0	1
Outsourcing Intang	0.131	0.339	0	1
Outsourcing Tang	0.17	0.377	0	1
Control variables				
Spatial Proximity*	124.269	29.524	88.078	206.623
Green R&D	0.511	0.501	0	1
Age*	16.483	15.57	1	121
Employees*	16.25	43.268	0	433.6
Share Export Sales*	9.071	20.454	0	100
Log GHG/VA	4.655	0.468	3.603	4.862
Group	0.115	0.32	0	1
Motivation for environmental innovation controls				
Existing regulations	0.357	0.480	0	1
Expected regulations	0.258	0.438	0	1
Financial incentives	0.247	0.432	0	1
Current or expected market demand	0.225	0.418	0	1
Good practice	0.197	0.399	0	1
Internal procedures	0.186	0.39	0	1
Geographical controls				
Emilia-Romagna	0.247	0.432	0	1
Friulia Venezia Giulia	0.148	0.356	0	1
Trentino Alto Adige	0.186	0.39	0	1
Veneto	0.417	0.494	0	1

Asterisked variables have been reported without natural log transformation for the ease of interpretation. All variables, with the exception of the Geographical controls and *Log GHG/VA*, are firm-level measures. *Log GHG/VA* is measured as the industry level.

Table 3: Correlational table

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	Outsourcing Intang	1							
(2)	Outsourcing Tang	0.515	1						
(3)	Log Spatial Proximity	-0.001	0.045	1					
(4)	Green R&D	0.186	0.092	-0.066	1				
(5)	Log Age	-0.144	-0.086	-0.097	0.02	1			
(6)	Log Employees	-0.077	0.023	-0.067	0.315	0.51	1		
(7)	Log Share Export Sales	0.011	0.027	0.044	0.061	-0.074	-0.001	1	
(8)	Log GHG/VA	-0.133	-0.075	-0.101	-0.05	0.385	0.273	-0.116	1
(9)	Group	0.012	-0.026	0.054	0.044	-0.189	-0.04	0.141	-0.303

Table 4: Probability of introducing an $EICO_2$

	(1)	(2)
Outsourcing	0.2969	
	[0.4953]	
Outsourcing Tang	-	1.6303***
		[0.5462]
Outsourcing Intang	-	-1.7136**
		[0.7522]
Green R&D	1.6616***	1.8206***
	[0.5711]	[0.5992]
Log Age	0.0433	0.036
	[0.3342]	[0.3231]
Log Employees	-0.0658	-0.1741
	[0.2154]	[0.2215]
Log Share Export Sales	0.3478**	0.3538**
	[0.1427]	[0.1433]
Group	-0.8801	-0.8875
	[0.7377]	[0.7527]
Log Spatial Prox	1.4934	1.7345
	[1.8285]	[1.9098]
Log GHG/VA	-0.4671	-0.5832
	[0.5419]	[0.5485]
Internal procedures	-0.6181	-0.6408
	[0.5903]	[0.6065]
Geographical dummies	Inc.	Inc.
Motivation dummies	Inc.	Inc.
Log-likelihood	-66.5186	-63.2287
McFadden's R^2	0.3465	0.3788
Wald $\chi2$	58.2946[17]***	56.7651[18]***
Observations	182	182

∗ $p < 0.1$, ∗∗ $p < 0.05$, ∗∗∗ $p < 0.01$. The dependent variable is the probability to eco-innovate in terms of CO2 emissions abatement. Robust standard errors and degrees of freedom are in parentheses. Identical results are obtained for column (1) when *Outsourcing* is measured as a count variable to better capture the different degrees of vertical disintegration.

Table 5: Instrumental variable estimates

	First-stage *Tangibles*	First-stage *Intangibles*	IV	IV LIML
	(1)	(2)	(3)	(4)
Outsourcing Tang			0.6377**	0.8762**
			[0.2544]	[0.3998]
Outsourcing Intang			-0.7472***	-0.9198**
			[0.2855]	[0.4038]
Knowledge rel	0.1759*	0.3142***		
	[0.1019]	[0.1035]		
Product rel	0.1752	0.2131*		
	[0.1177]	[0.1140]		
Social Cap	-0.087	0.0459		
	[0.0654]	[0.0534]		
Pre-det Size	0.0160***	0.0018		
	[0.0055]	[0.0050]		
Unionisation	-1.9096*	0.0933		
	[1.0047]	[0.8139]		
Green R&D	0.0325	0.0262	0.2432***	0.2475***
	[0.0804]	[0.0731]	[0.0781]	[0.0854]
Log Age	0.0072	0.0086	-0.0607	-0.0714
	[0.0530]	[0.0493]	[0.0608]	[0.0679]
Log Employees	-0.035	-0.0292	-0.0192	-0.0326
	[0.0514]	[0.0350]	[0.0366]	[0.0474]
Log Share Export Sales	-0.0234	-0.0104	0.0578**	0.0628**
	[0.0233]	[0.0214]	[0.0245]	[0.0267]
Group	0.07	0.0181	0.0869	0.0699
	[0.1228]	[0.1197]	[0.1488]	[0.1571]
Log Spatial Prox	-0.2149	0.3156	-0.0312	0.0304
	[0.3669]	[0.2794]	[0.3163]	[0.3611]
Log GHG/VA	0.0922	-0.075	-0.128	-0.1614
	[0.1252]	[0.1585]	[0.1463]	[0.1555]
Internal procedures	-0.0451	0.0328	-0.1076	-0.0946
	[0.0743]	[0.0758]	[0.0886]	[0.0965]
Geographical dummies	Inc.	Inc.	Inc.	Inc.
Motivation dummies	Inc.	Inc.	Inc.	Inc.
Hansen J test	-	-	4.8793[3]	4.1098[3]
Endogeneity test	-	-	6.1044[2]**	
Kleibergen & Paap F test	-	-	3.1309	
Observations	116	116	116	116

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The Dependent Variables for specifications (1) and (2) are Outsourcing Tang and Outsourcing Intang, respectively. Specification (3) is estimated with the 2 step efficient GMM estimator and specification (4) is estimated with LIML estimator (Baum et al., 2007). The endogeneity test is robust to heteroschedasticity (Hayashi, 2000). For details on the weak instrument test of Kleibergen & Paap refer to Baum et al. (2007). Sargan-Hansen test of overidentifying restrictions is reported. Robust standard errors and degrees of freedom are in parentheses. *Pre-det size* has missing values for 66 companies thus reducing the number of observations to 116 compared to other estimates.

Table 6: Sample selection - Heckman probit

	Selection Equation ***(Green R&D)***	**Outcome Equation** ***(EICO2)***
	(1)	(2)
Outsourcing Tang	0.1169	1.0502*
	[0.3480]	[0.6247]
Outsourcing Intang	0.835*	0.9510*
	[0.5032]	[0.5405]
Log Age		0.0209
		[0.2625]
Log Employees	0.4242***	0.1551
	[0.0856]	[0.1412]
Log Share Export Sales		0.1346
		[0.1213]
Log Spatial Prox		0.5409
		[1.4126]
Log GHG/VA		0.2095
		[0.5196]
Group		0.598
		[0.6708]
Internal procedures	0.7394**	0.6098*
	[0.2986]	[0.3688]
Knowledge rel Uni	0.7328*	-
	[0.3766]	
Geographical Dummies	Inc.	Inc.
Motivation dummies	Inc.	Inc.
Wald test of indep. eq. ($\rho = 0$)	$\chi 2$ (1) = 0.31	
Log-likelihood	-134.8984	
Observations	182	

$*$ $p < 0.1$, $**$ $p < 0.05$, $***$ $p < 0.01$. Robust standard errors and degrees of freedom are in parentheses.

Table 7: Other types of eco–innovation

	Eco–innovation (Overall)	**Eco–innovation (Product)**	**Eco–innovation (Process)**
Outsourcing Tang	1.2872**	1.0068*	1.1742*
	[0.6092]	[0.6100]	[0.6049]
Outsourcing Intang	-2.0034***	-1.5966***	-2.1907***
	[0.6317]	[0.5974]	[0.6555]
Green R&D	1.9372***	1.8559***	1.8516***
	[0.5146]	[0.5306]	[0.5110]
Log Age	-0.3422	-0.2728	-0.2942
	[0.2570]	[0.2517]	[0.2636]
Log Employees	0.0878	0.0877	0.0912
	[0.1897]	[0.1939]	[0.1924]
Log Share Export Sales	0.189	0.2444*	0.2066*
	[0.1250]	[0.1261]	[0.1251]
Group	-1.0516	-1.2597*	-0.9951
	[0.7408]	[0.7293]	[0.7651]
Log Spatial Prox	1.5824	1.6478	1.7295
	[1.6589]	[1.6928]	[1.6281]
Log GHG/VA	-0.9151*	-0.8297*	-0.7657
	[0.5190]	[0.4745]	[0.5246]
Internal procedures	-0.5401	-0.3352	-0.4851
	[0.5313]	[0.5403]	[0.5328]
Geographical dummies	Inc.	Inc.	Inc.
Motivation dummies	Inc.	Inc.	Inc.
Log-likelihood	-75.4907	-74.2214	-74.6239
McFadden's R2	0.3534	0.3484	0.3571
Wald $\chi 2$	52.1828(18)***	53.7645(18)***	54.1577(18)***
Observations	182	182	182

$*$ $p < 0.1$, $**$ $p < 0.05$, $***$ $p < 0.01$. Robust standard errors and degrees of freedom are in parentheses.

Table 8: Quantification of effects

	Eco–innovation (CO2) %	**Eco–innovation (Overall)** %	**Eco–innovation (Product)** %	**Eco–innovation (Process)** %
	(1)	(2)	(3)	(4)
Outsourcing Tang	27.3	28.62	20.94	25.67
Outsourcing Intang	-13.3	-25.74	-20.42	-26.52

Effects should be interpreted as the % change in probability to eco-innovate due to different types of outsourcing activities.