CO_2-reducing innovations and outsourcing: evidence from photovoltaics and green construction in North-East Italy.♦

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Abstract

The paper investigates whether innovations entailing a perceived reduction of CO2 emissions are related to outsourcing. Some research hypotheses are put forward and tested on a sample of firms in two key 'green-industries', sustainable buildings and photovoltaics, in a regional context (North–East Italy) for which detailed survey-based information could be collected. An impact on CO2 reducing innovations is found for the externalisation of tangible activities only, as opposed to intangibles, whose outsourcing even decreases them. The results are robust in econometric terms, and suggest some new environmental implications of the standard 'make-or-buy' decisions of firms.

Keywords: environmental innovations; CO2 reduction; outsourcing.

JEL codes: Q55, 032, L23, L24.

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1. Introduction

The reduction of CO_2 emissions is one of the most urgent policy objectives for the achievement of sustainable economic growth. Like the others, also this environmental objective requires a system transition at the societal level, an important part of which is on firms' shoulders (Geels, 2010). In particular, companies could pursue it through the introduction and/or adoption of eco-innovations[1] (EIs) leading to a reduction of their CO_2 footprints (henceforth EICO2). Within this domain, EICO2 refer to innovations with environmental benefits deriving from the production of goods or services, rather than from their after-sales use. They are accordingly considered as process kinds of EIs (Cleff and Rennings, 1999).[2] From a slightly different perspective, EICO2 have also been included among those EIs that, unlike others (e.g. those reducing the use of energy or materials per unit of output), affect the profitability of the adopting firms, but do so only indirectly (Ghisetti and Rennings, 2014).

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[1] EIs can be defined as "the production, assimilation or exploitation of a product, production process, service or management or business methods that is novel to the firm [or organization] and which results, through-out its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives" (Kemp and Pontoglio, 2007, p.10).

[2] Conventionally included in the same group are also EIs categories that entail (following the European Community Innovation Survey (CIS)'s classification): reducing material use per unit of output; reducing energy use per unit of output; replacing materials with less polluting or hazardous substitutes; reducing soil, water, noise, or air pollution; and recycling waste, water, or materials. Examples of product EIs are instead those that entail: reducing energy use; reducing air, water, soil or noise pollution; improving the recycling of products after use.

EICO2 are eco-innovations of which present and future regulations are among the most important drivers (Horbach, 2008) exerting an important 'push/pull effect' on firms' incentives to curb the typical 'double-market-failure' of EIs (Rennings, 2000; Jaffe et al., 2005; Jiménez, 2005; Del Río González, 2009): that is, a socially excessive EICO2 footprint, and a socially insufficient amount of knowledge (R&D) for its reduction. However, recent studies from diverse backgrounds (e.g. ecological and innovation economics) have shown that regulations do not operate in the EI realm alone: they interact with other techno-economic drivers (Horbach et al., 2012), such as R&D, human capital, organisational practices, external cooperation (e.g. Ghisetti et al., 2015; Cainelli et al., 2015; Ketata et al., 2014; De Marchi and Grandinetti, 2013; De Marchi, 2012). Among these drivers, no attention has yet been devoted to firms' decisions to outsource their business activities (see McIvor, 2005), [3] an issue that has been extensively covered for standard innovations instead (e.g.

[3] While stating this point, we are aware of the growing body of literature on the impact that international outsourcing (i.e. offshoring) has been claimed to have on the environmental performances of firms, which use it to relocate 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) (Jeppesen et al., 2002; Brunnermeier and Levinson, 2004; Levinson and Taylor, 2008; Wagner and Timmins, 2009). However, this research question, related to the environmental role of regulatory asymmetries across countries, is different from ours, in that it is related to outsourcing *per se*. Furthermore, as we shall see, our focal firms are locally inter-connected and characterised by a very low level of the penetration of international markets and offshoring to which the PHH refers. Finally, while it could be argued that the two 'green' sectors of our analysis are involved in the production of environmentally sustainable goods and commodities, and thus are more sensitive to CO2 emissions, our dependent variable, i.e. EICO2, cannot be directly and completely equated to them.

Robertson and Langlois, 1995; Windrum et al., 2009), and which we claim to be potentially relevant for EIs, and EICO2 in particular.

The present paper intends to fill this gap by addressing the following research questions: (i) Does the degree of vertical disintegration of firms affect their capacity to carry out eco-innovative activities with an impact on their CO2 footprints? (ii) Does the kind of sector in which firms operate matter? (iii) Does the kind of activity externalized affect this specific eco-innovative capacity?

Answering these questions would possibly enlarge the set of policy/strategy tools for firms to pursue a Porterian 'win-win' effect: that is, increase their competitiveness by innovating while complying with regulations that policy-makers set in order to have environmental benefits (Porter and van der Linde, 1995; Ambec et al., 2013). This would be particularly important for sectors on which a smart and sustainable kind of growth intensively relies to meet the targets of environmental policies in terms of CO2 reduction. These arguments justify the choice of the focal industries of our analysis, i.e. photovoltaics and sustainable buildings (or 'green buildings'): two of those most frequently found in the taxonomies of 'green industries' (Salvatelli, 2014), and for which we have been able to collect, through a dedicated survey, detailed information on a sample of firms in North-East Italy.

The paper is structured as follows. In Section 2 we review the literature on (standard) innovation and outsourcing, and try to extend the review's results to the case of EICO2 by putting forward our research hypotheses. In Section 3 we present the empirical application with which we test those hypotheses. Section 4 illustrates the results. Section 5 concludes with some comments on the relevance and possible future extension of our results.

2. Theoretical background

In the absence of specific studies on the topic, the only way to proceed is to draw eclectically on the literature about 'standard' innovation and outsourcing, and look 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 which 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 using them to experiment with different processes of resource-sharing and learning-by-interacting (Robertson and Langlois, 1995; Windrum et al., 2009). The desirability of outsourcing versus vertical integration in terms of innovation should be established on more specific bases. It depends, among others, on: i) the kind of innovation that it may lead to; ii) the characteristics of the industry in which it occurs; iii) the nature of the externalised activities. In what follows, we address each of these issues in turn with respect to our specific kind of eco-innovation, i.e. EICO2, and to the 'green' kind of industries to which our application refers.

2.1 Kinds of innovation: incremental vs. radical

Among the various characteristics of technological innovation, the one most sensitive to outsourcing appears to be its degree of novelty. Radical technological breakthroughs require firms to cope with a great deal of uncertainty and to undertake strongly interdependent development efforts by different functions, which would thus be inconsistent with the decentralisation logic of outsourcing (Gonzalez-Diaz et al., 2000). By contrast, incremental innovations – and those among them which consist in rearranging the components of existing product architecture (Henderson and Clark, 1990) – may benefit from outsourcing through the diversity of information signals and competencies of the providers (Robertson and Langlois, 1995; Mahnke, 2001).

Extending this argument to EICO2 would require ascertaining whether these are radical or incremental innovations by considering also, and especially, the type/intensity of their environmental impact. A useful starting point in this regard is the 'design rationale' of an EI, by which is meant the way in which it aims/manages to deal with the environmental impact of (in this case) business activities.[4] Following Carrillo-Hermosilla et al. (2010), design rationales can be classified in different types spanning from 'component addition', through 'sub-system change', to 'system change' which entail progressively increasing levels of radicalness and activeness on the processes/systems that generate an environmental impact.[5]

Although with the benefit of hindsight, our tentative argument is that EICO2, due to their inner heterogeneity, do not yet implement the most radical of these three design rationales. On the one hand, EICO2 in general are marked by more novelty than simple *component level*

[4] An alternative approach 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) – on the basis of which interesting classifications have been proposed (see, for example, Brezet, 1997; Ehrenfeld, 2001). However, this methodology requires reference to specific instances of EI and would not be suitable for our focus on a typology of them, such as EICO2.

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

changes "[that] minimize and repair negative impacts without necessarily changing the process and system that generate those impacts in the first place" (Carrillo-Hermosilla et al., 2010, p. 1076), as in the case of end-of-pipe technologies. However, given the currently envisaged reduction targets, EICO2 are far less radical than EIs entailing the "redesign of entire systems towards more "eco-effective" [and not only eco-efficient] solutions" (ibid.), that is, *system changes*. Most of the EICO2 which have been introduced so far fit at most with the intermediate level of radicalness of the *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, emphasis added). [6]

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 as to require the pursuit of vertically integrated organizational structures. On the contrary, we expect that, as in the case of technological innovations, a greater degree of outsourcing is 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:

[6] Our conjecture is consistent with the recent appraisal of the three technological trajectories of CO2 capture envisaged at the time of writing: 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 improvements of coal power plants. Only the third, used in Integrated Gasification Combined Cycle (IGCC) power plants, is considered radical, but it is still in need of not yet available components (e.g. gasifier and gas turbine) (Rennings et al., 2013).

HP1a: *In general, EICO2 could benefit from a higher degree of firm's vertical disintegration.*

2.2 Industry characteristics: Schumpeter Mark I vs. Mark II

Another important element in the impact of firms' degree of vertical disintegration on innovation is the industry environment in which they operate, in particular in terms of technological regimes and sectoral systems of innovations (Breschi et al., 2000). In some industries – Schumpeter Mark I regime (or 'entrepreneurial regime') – innovation follows a pattern of 'creative destruction' in which outsourcing can be functional to accessing external knowledge and competencies, and to accelerating 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') – where innovation is instead driven by 'knowledge accumulation', outsourcing may be even detrimental to innovation because the entailed problems of knowledge leakage with respect to the providers may expose the client firms to attempts at imitation by their competitors.[7]

Extending the previous argument to the two 'green industries' of our analysis is difficult also, and especially, because of the heterogeneous cases of industrial dynamics that they encompass. In all of them, however, an important element intervenes and interacts with the underlying technological regime to affect its dynamics: the role of policy (Oltra and Saint

[7] Outsourcing appears even more pivotal in more detailed regimes classifications which more explicitly address the characteristics of the knowledge bases and the sources of barriers to entry. In Marsili (2002)'s taxonomy, for example, outsourcing is a key innovation element in 'complex systems' regimes, as distinguished from science-based, fundamental processes, product engineering and continuous processes.

Jean, 2009a). The need/will to comply with the extant regulation tends to stimulate firms in these sectors to improve their environmental performances by adhering to a viable dominant design and gradually innovating around it (Mazzanti et al., 2014). 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.[8] Further elements supporting this argument come from the local and related kind of variety that characterises the dynamics of both the patent and the R&D portfolios of firms in green oriented sectors (Frenken et al., 2004; Oltra and Saint Jean, 2009b). 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). If, on the basis of the previous argument, outsourcing is conceived as favouring (hampering) innovation in dynamic (cumulative) regimes, we expect that the specific kind of sectoral systems of innovation that we address attenuates the EICO2 impact, or even reverses it, leading to a specific version b) of our previous Hp1a.

HP1b: *In green industries, EICO2 do not benefit from the firm's vertical disintegration.*

2.3 Externalised activities: tangibles vs. intangibles

Another relevant aspect to consider in regard to the impact of EICO2 is the kind of activities subject to outsourcing. From a contractual perspective, outsourcing could provide firms with efficiency gains exploitable in innovating only in the case of non-specific tangible activities, because intangibles are more difficult to specify/verify in market transactions and more

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

exposed to hold-up problems (Williamson, 1975; Gonzalez-Diaz et al., 2000).[9] From a different evolutionary perspective (Mahnke, 2001), internal resources (e.g. labour) could be made functional to strategic innovations in the aftermath of outsourcing, but with the exception of core competencies, whose externalisation entails the risks of losing control, de-coupling from other complementary activities, and information leakage.[10] Combining these two complementary perspectives (Arnold, 2000), the standard argument for technological innovation is that a positive impact on it should accrue from the externalisation of all activities except those for which short-run operative costs are too high and long-term strategic aspects potentially compromised.

The extension of the previous argument to our context of analysis is more straightforward than in the previous two cases. The distinction between tangible and intangible assets similarly applies to firms operating in green sectors, which face the decision of whether to introduce/adopt EICO2. Furthermore, the core activities of firms involved in this specific context appear to be, as far as the intangible ones are concerned, among those with high value-added in business terms. This is certainly the case of R&D, which is deemed crucial in complementing the basic research and public technology programmes on which CO2 emissions still largely depend (Horbach et al., 2012, p. 117). But similar evidence of an impact on both energy efficiency and carbon footprint in green sectors has been found also

[9] Following the seminal work by Corrado et al. (2005), and the standard taxonomy compiled by NESTA within the “Innovation Index Project”, we refer here to the following 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.

[10] 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).

for Information Technologies (IT) (e.g. Faucheux and Nicolai, 2011), organizational monitoring and quality-control (such as ISO schemes, EMAS and other environmental management systems) (e.g. Cainelli et al., 2010), as well as for marketing, design and related (e.g. trademarks) activities (Veryzer, 2005; Horbach et al., 2012).[11]

For all of these idiosyncratic activities, we expect that outsourcing hinders 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 to emerge in normal conditions (i.e. with low asset specificity). In brief, our second hypothesis is:

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

3. Empirical application

3.1 The empirical setting: green industries and regional context

The previously described hypotheses are tested with respect to a specific empirical setting, whose choice has been determined by a combination of relevance and data availability: that is, photovoltaics and green construction in North-East Italy. As well known, these are two

[11] Although in sectors other than green ones, EICO2 has also 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 important for their outsourcing analysis.

key 'green industries' on whose development the achievement of environmental targets of the kind investigated here crucially depends (Salvatelli, 2014). The photovoltaic industry belongs among the second-generation technologies of the renewable energy industry. It mainly consists of the production of solar cells converting light into electricity. In our geographical context, i.e. Italy, the photovoltaic industry has recorded impressive growth: in the 2007-2012 period, solar photovoltaic installations and capacity growth rates were respectively 123% and 185% (GSE, 2012). Sustainable building (also known as green construction), instead, expands and complements the classical concerns of the construction industry relative to the economy, utility, durability, and comfort of buildings. In particular, sustainable building concentrates on structures and processes that are environmentally responsible and resource-efficient throughout the building's life-cycle: siting, design, construction, maintenance, renovation, and demolition (Anink et al., 1996). Both of these two green sectors are of course involved in the struggle to reduce CO2 emissions, especially through the introduction of EICO2. However, the available statistical evidence allows us to ascertain this involvement in only rough terms.[12]

[12] Unfortunately, it is difficult to gather aggregated statistics on the two sectors because no official industrial classification exists and relevant measures (e.g. environmental innovation for CO2 abatement) are not available at a fine-grained level of detail. Nevertheless, as confirmed by the construction of the firms' population for the present work (see Section 3.2), we expect a reasonable majority of companies operating in these two sectors to be included in the following three NACE rev. 2 industry codes: C16 "Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials", C27 "Manufacture of electrical equipment" and F "Construction". We thus compare the probability of carrying out environmental innovation for CO2 abatement in these three industries with other relevant industries to check the importance of photovoltaics and green construction compared to other industries in the issue at stake. In particular, we retrieve

While of general relevance to the issue at stake, the structure and dynamics of these industries take on interesting specifications in contexts marked by those local phenomena – such as firms' co-location, social embeddedness, network (rather than scale) economies, and the like – to which regional and urban studies usually refer (e.g. Cainelli et al., 2012; Mazzanti and Zoboli, 2009). In particular, outsourcing and other business relationships embedded in the territory (e.g. cooperation and technology transfer) emerge as idiosyncratic drivers of both technological and eco-innovations of the kind that we consider here (Mazzanti et al., 2009; Antonioli et al., 2014). This local specification of the green industry phenomenon has been one of the topics of a recent international research project, called OPENLOC (http://openloc.unitn.it/), within which a dedicated survey has been carried out on the two focal industries of the paper, with respect to four administrative regions (NUTS 2) in 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, with levels and rates of growth of GDP above the national average, and 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 for testing our research hypotheses for three reasons. First, they represent an area characterised by a flexible specialisation system in general, with a widespread presence of

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information from the aggregated version of the Community Innovation Survey 2008 available from Eurostat (http://ec.europa.eu/eurostat/web/science-technology-innovation/data/database). The selected industry codes exhibit an above-average probability of conducting environmental innovation for CO2 abatement (C16 – 15.75%, C27 – 17.69% and F – 5.37%) compared with overall manufacturing (15.3%). These statistics also show a value comparable to that of other high-polluting industries: transportation (15.78%), mining (20.18%) and water collection, treatment and supply (14.55%).

SMEs, where outsourcing of production stages is the norm (Brusco, 1982). Second, the area is characterised by the active integration of communities of people and populations of industrial firms, which make 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.[13] This enables us to test the EICO2 impact of outsourcing in general for firms that, while operating in ecological sectors, are embedded in different economic and institutional settings.

3.2 Data

The sample used in this paper was extracted from an original database developed in 2011 by the joint efforts of the Departments of Economics of the Universities of Bologna and Trento (Italy) within the above-mentioned OPENLOC research project. A professional polling institute administered a structured questionnaire between October and December 2010 through telephone interviews with the owners–managers.

Given the absence of a clear-cut industrial classification for photovoltaics and sustainable buildings, the firms' population was 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 in professional 'green' exhibitions (Legno e Edilizia held in

[13] For 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 occupy 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/.

Verona, 17-20 March 2011; Ecocasa Expo held in Reggio Emilia, 3-6 March 2011; Impianti solari Expo held in Parma, 25-27 March 2011); and (iv) a list of firms registered with 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 by administrative region (the second level in the Nomenclature of Territorial Units for Statistics codes) and by industry segment (mainly 16 and 27 NACE rev. 2 codes). We combined the information from the survey with balance sheet information at the company level (e.g. turnover for the pre-sample year 2005) from Bureau van Dijk's database AIDA and Unioncamere. Full information was finally obtained for 185 out 213 firms. This final sample is representative of the overall population of the 931 companies by region and industry segment ($\chi^2[3] = 0.3$ and $\chi^2[1] = 0.12$, respectively).

With respect to the final sample of 185 companies, three sets of information are available for the period 2006-2010. First, information on their EIs, with a disaggregation of their types with respect to their perceived environmental impact in the aftermath of their introduction/adoption (e.g. pollution reducing vs. energy saving). Second, the dataset has information on specific aspects of the 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 the determinants of EICO2 (e.g. green R&D, motivations to carry out EI), as well as for the structural characteristics of the focal firms (e.g. size, age, etc.).

3. 3 Dependent variable and econometric model

The dependent variable of our empirical exercise is the introduction of new (or significantly improved) environmental innovations with an impact on the reduction of CO2 emissions (EICO2). Following the Community Innovation Survey (CIS) 2008,[14] respondent firms were asked questions addressing the environmental benefits deriving from product, process, service, organisational and marketing innovations. Among these, we made use of a question in which companies had to refer to the reduction of the CO2 'footprint' (total CO2 production) eventually deriving from their eco-innovations.[15]

Operationally, we define EICO2 as a dummy variable equal to 1 if the firm introduced an environmental innovation entailing 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:

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

where $\Lambda(z) = (e^z/(1 + e^z)$ is the logistic function. Y_i is the above-described dependent variable, 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 indicates a series of firm-specific control variables.

[14] The *Community Innovation Survey 2008* is produced under the coordination of Eurostat (OECD/Eurostat, 2005). It covers the period 2006–2008 and includes sixteen countries. Firms with at least 20 employees answer questions related to: how they innovate, their innovation projects and their objectives, their internal and external sources of R&D, the sources of information, cooperation to innovate (a description is in Mairesse and Mohnen, 2010). For the first time the CIS 2008 comprises a special environmental section.

[15] Although the question doesn't ask about the actual extent of the reduction of the footprint, it is formulated in a way such to make firms answer on the basis of an ex-post self-evaluation of the CO2 effects of their EIs.

Because some unobserved covariates may be simultaneously correlated with EICO2 and outsourcing variables, thus biasing the coefficients, we instrument the outsourcing variables (in particular, of tangibles and intangibles) with a set of exogenous variables (see Section 4.2.1 for further details). Furthermore, we control for the possibility of self-selection in terms of the group of companies undertaking green R&D (see Section 4.2.2 for further details) in order to deal with the probability that estimation of our model may lead to biased results (Love and Roper, 2002; Piga and Vivarelli, 2004).

3.4 Independent and control variables

Our main independent variables are three measures of outsourcing decisions with respect to the 17 different activities that the OPENLOC survey distinguishes (see the list below). A first measure refers to the firm's overall reliance on outsourcing (*Outsourcing*), and takes on value 1 if the firm has carried out any of the 17 types of outsourcing activity in the period 2006-2010 and 0 otherwise.[16] The other two measures of outsourcing are obtained by grouping the 17 activities into two classes: tangible and intangible activities. *Outsourcing tangibles* is a dummy variable taking value 1 if the firm outsourced any of the following 9 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. *Outsourcing intangibles* takes value 1 if the firms outsourced any of the following 8 activities: marketing, research & development,

[16] In order to test for different degrees of vertical disintegration, we also construct 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 the results are available upon request.

project design, human resource management, information systems, enterprise resource planning, quality control, development of IPRs.[17] The relative descriptive statistics show quite differentiated recourse by the sampled firms to the different kinds of outsourcing (Table 1), with the externalisation of tangibles being more frequent than intangibles, especially for EICO2 innovators.

[INSERT TABLE 1 ABOUT HERE]

The other co-variates refer to the factors most likely to influence the adoption of EIs with an impact on CO2 abatement. In particular, we control for the EI 'push/pull' role of regulations and for the institutional aspects. Therefore, we make use of dummies for motivations linked to existing environmental regulations or taxes on pollution (*Env regulations*), and to the availability of government grants, subsidies or other financial incentives (*Env financial incentives*).[18] Finally, in order to take into account specific regulations enacted at the regional administrative level, we also include a set of four

[17] The distribution of companies by type of outsourcing is the following: 141 firms have neither type of outsourcing, 16 have only tangibles, 12 have only intangibles, and 16 have both.

[18] While this choice could be criticised for referring to regulatory aspects that are only 'perceived', we deem it preferable to the alternative of referring to more 'objective' evidence of them only available at the regional and/or industry level, such as the ratio between greenhouse gases (GHGs) and value added (VA). While in principle possible, using regulatory stringency variables at the regional level yields an expected high correlation with our geographical dummies, with possible problems of multi-collinearity. In the same respect, for the sake of parsimony we also chose to drop other motivations for eco-innovating not directly linked to the same regulatory aspects (e.g. current or expected market demand from customers).

geographical dummy variables defined for the four administrative regions (*Emilia Romagna, Friuli Venezia Giulia, Trentino Alto Adige and Veneto*).

As for other non-regulatory co-variates, we first include a dummy (*Green R&D*), taking value 1 if the firm has invested resources in R&D with the specific aim of reducing its environmental impact in the 2006-2010 period, and 0 otherwise. We also build a dummy (*Internal procedures*) to control for the firm having internal procedures in place to regularly identify and reduce its environmental impacts (e.g. ISO 14001 certification, environmental audits, etc.) (Angel and Rock, 2005).

Finally, we include a number of controls for firms' structural characteristics. 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. *Log Age* represents the (natural) logarithm of firm age (plus one) in 2010. We also include a variable for the international orientation of the firm (*Log Share Export Sales*), defined as the (natural) logarithm of the shares of exports in sales (plus one) in the 2006-2010 period. Finally, *Group* is a dummy variable that takes value 1 if the firm is part of an industrial group and 0 otherwise.

Table 2 provides the descriptive statistics and Table 3 reports the correlation matrix for the main variables, showing that the bivariate correlations among our main variables are generally weak. There is no indication of significant multi-collinearity amongst the independent variables. The Variance Inflation Factor ranges from 1.07 to 2.32, well below the accepted threshold level of 5 (Menard, 1995, pag. 66).[19]

[19] As the tetrachoric correlation between our main explanatory variables (*Outsourcing tangibles* and *Outsourcing intangibles*) is 0.704, we run few additional diagnostic tests to spot any problem of multicollinearity. In particular, the condition index for the explanatory variables ranges between 1 and 3.31,

[INSERT TABLE 2, TABLE 3 ABOUT HERE]

4. Results

This section presents and discusses the results of the econometric estimation procedure. However, our baseline estimates rely on a cross-sectional database, with the consequence that they may be affected by problems of endogeneity and selection bias. For this reason, we have decided to present the baseline model together with a battery of robustness checks. Indeed, as in several other papers dealing with cross-sectional data CIS-like questionnaires, endogeneity and selection bias are quite common sources of distortion of the results (e.g. Crepon et al, 1998; Mohnen and Röller, 2005). Therefore, we will discuss the baseline model (in Section 4.1) quite briefly, then focusing our attention (in Section 4.2) on the analysis that presents the results with the appropriate procedures to test and correct the two distortions of endogeneity and selection bias.

below the threshold value of 30 (Hair et al, 1998, pag. 220). We also compute the Theil R2 multicollinearity effect. It equals 0.152 which is well below the value indicating multicollinearity, i.e. 1 (Theil, 1971). We are indebted to the Associate Editor for this helpful suggestion.

4.1 Baseline model

4.1.1 Outsourcing and EICO2

The first set of results that we present refers to a firm's outsourcing of any of its economic activities,[20] the estimates of which are shown in column 1 of Table 4. The probability of introducing an eco-innovation with a CO2 impact is positively related to 'green R&D'. This result supports the specific nature of the innovation concerned, 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 it is targeted on solving problems in a dedicated green realm. This result is further confirmed by the positive impact of the two regulatory co-variates (*Env regulations* and *Env financial incentives*). Both of them are highly significant and positive. This provides supplementary evidence on the very specific nature of the innovative processes that we are dealing with.

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 the findings of other studies on the need for local firms to comply with more numerous and stringent

[20] To be noted in this regard is that, while the actual location of the provider is not known from the dataset, this general outsourcing can be deemed mainly domestic and as comprising offshoring operations to only a limited extent. In fact, the degree of internationalisation of the sample firms is quite low, since only 4.8% of them have foreign equity participation and only 3.78% of firms conducted FDI in the period 2006–2010. Moreover, the largest proportion of these FDI are made within the EU15 area (85% of cases). On this basis, we feel confident that our empirical application actually refers to a context in which outsourcing is instrumental for a local kind of labour division, rather than for entering global value chains or possibly exploiting international symmetries in environmental regulations.

environmental regulations on CO2 when operating on the global markets, and on their need to have an environmental reputation to compete on those markets (Cainelli et al., 2012).

Once general outsourcing is inserted into the model to test our research hypotheses, this co-variate turns out to be not significantly correlated with EICO2 (Column 1 of Table 4). HP1a, referring to the kind of innovation (radical vs. incremental) that EICO2 represents (Section 2.1), is thus not supported, and nor is its opposite specification in HP1b considering the technological regimes in which firms operate. One possible explanation of this result could be the possible counterbalancing effects of the two hypotheses. While the (still) non-radical nature of EICO2 may provide more vertically disintegrated firms with a potential advantage in their adoption (Section 2.1), the Schumpeter Mark II nature of the sectors in which our firms operate could make this potential vanish, given the negative strategic implications of a higher degree of vertical disintegration in this setting (see Section 2.2).

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.

4.1.2 Tangibles vs. intangibles outsourcing and EICO2

The probability of introducing an EICO2 turns out to be significantly related to outsourcing, once this latter variable is split into its tangible and intangible objects. Columns 2 and 3 of Table 4 show results for *Outsourcing tangibles* and *Outsourcing intangibles* separately, while column 4 reports results for the full specification including both variables. In all the different specifications, both variables are statistically significant and, in accordance with our theoretical framework, they have opposite effects. The outsourcing of tangible assets has a positive correlation with EICO2, while that of intangible ones has a negative sign.

Our second hypothesis (HP2) is thus confirmed. While the propensity to eco-innovate with a reduction of the CO2 footprint is higher for those firms that have externalised some of their tangibles, not only does the externalisation of intangibles hamper EICO2, it also makes it less possible. As said, this last result finds a first consistent explanation in the higher contractability problems that intangibles pose with respect to tangibles, as could happen elsewhere according to standard transaction costs arguments. A more specific explanation can instead be found by adopting a resource/competence-based perspective. It points to the strategic value that the identified intangibles have for eco-innovating, in terms of CO2 in particular, in the two sectors that we are considering. Accordingly, their externalisation may involve a loss of control over core activities and knowledge that eventually impoverishes the firm's EICO2 capacities.

[INSERT TABLE 4 ABOUT HERE]

4.2 Robustness checks

As already said, our baseline estimates may be affected by serious distortions, mainly due to the cross-sectional nature of the data collected. On the one hand, it may be that highly EICO2-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, a lower propensity to outsource intangibles may be due to the higher sensitivity to the relative problems of more EICO2-innovative firms (Gorg and Hanley, 2011).

On the other hand, a further issue that may affect our baseline estimates is related to self-selection. This would stem from the consideration that the probability of outsourcing intangibles may be strongly correlated with our *Green R&D*, yielding biased estimates for our focal relationship between *Outsourcing of intangibles* and EICO2. Indeed, as highlighted by an extensive body of literature (Veugelers, 1997; Veugelers and Cassiman, 1999), it is reasonable to expect a certain degree of complementarity between the probability of contracting-out intangible activities (of which R&D is an integral part) and the probability of conducting (green) R&D activities in-house.

There consequently follows a quite extensive section on a set of robustness checks conducted in order to address these issues. In particular, Section 4.2.1 deals with endogeneity, and Section 4.2.2 with selection bias. All robustness checks should be referred to the specification reported in column 4 of Table 4.

4.2.1 Endogeneity

We take endogeneity into account by instrumenting for the two of the three outsourcing variables that appear significant. As regards the outsourcing of tangible activities, we refer to the literature on the determinants of outsourcing decisions (Abraham and Taylor, 1996) and focus on three drivers of outsourcing for which a direct EICO2 impact can be excluded. First, with an increase in firm size, outsourcing becomes a progressively more efficient governance mode with which to subdivide the firm's value chain and benefit from external labour cost savings, as well as to enter international networks and exploit the opportunities that they offer (Mazzanti et al., 2009). Accordingly, we expect to find a positive correlation between *Outsourcing tangibles*, on the one hand, and the relative size of the focal firm in our sample, on the other, calculated for the pre-sample year 2005 as the normalised value of its turnover with respect to the average and standard deviation of the same sample (*Pre-det Rel Size*). Secondly, given its standard impact on higher wage costs and greater workers' participation in governance decisions (Mazzanti et al., 2009), we expect to find a negative relationship between the same outsourcing variable and the *Unionisation* of the area in which the firms are located. *Unionisation* is defined as the provincial ratio between the number of workers registered with the two most important unions in Italy (CGIL and CISL) and the total number of employed workforce in the pre-sample year 2005. Finally, greater recourse to the outsourcing of intangibles is expected in the presence of a higher level of social capital – proxied with the number of employees in social enterprises over the total in the pre-sample year 2005 (*Social Capital*) – given its role in reducing opportunistic, rent-seeking behaviours in market transactions (Burker and Minerva, 2013).

To construct the exclusion restrictions for *Outsourcing intangibles*, we instead resort to our survey and look at the presence of activities through which the sample firms have carried out knowledge transfer (*Knowledge rel*) and new product/service development cooperation (*Product rel*) with external partners.[21] In so doing, we assume that, unlike the structured and dedicated patterns of external knowledge search (e.g. in terms of breadth and depth) that firms follow in eco-innovating (Ghisetti et al., 2015), these external relationships may not be enough to enable firms to pursue EIs with a decrease in the CO2-footprint. Nevertheless, we consider the same activities as important sources of experience and competencies in

[21] More precisely, *Knowledge rel* is 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, *Product rel* takes 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.

identifying and dealing with the problems that the externalisation of intangibles entails (Montresor and Vezzani, 2016).

We report two different specifications of our IV model which confirm our baseline results (Table 5).[22] The first one (Columns 1, 2 and 3 of Table 5) uses a two-step efficient generalised method of moments (GMM) estimator which generates efficient estimates of the coefficients as well as consistent estimates of the standard errors, compared with the standard two-stage least square IV estimator (Hayashi, 2000; Baum et al., 2007). The second specification (Columns 1, 2 and 4 of Table 5) uses a limited-information maximum likelihood estimator (LIML) with the advantage of reporting more robust estimates to a possible weak instrument problem. To be noted is that, on running an endogeneity test robust to heteroskedasticity, our main explanatory variables turn out to be affected by a problem of endogeneity. The endogeneity test rejects the null hypothesis of exogenous regressors at the 5% significant level.

After controlling for this endogeneity problem, our main result on the relevance of the kind of externalised activities for EICO2 (that is, HP2) is confirmed. Indeed, this is the most important result of our study, in particular as regards the 'EICO2–hostile' impact of intangible outsourcing. In particular, its importance is increased on considering that, in the regional contexts investigated, the presence of diffuse social capital and a business-friendly institutional set-up (e.g. in terms of local banks and firms and workers' associations) usually attenuate the risk of opportunistic behaviours in market relationships like outsourcing, and generate learning-by-interacting phenomena with positive (eco-)innovative implications (Mazzanti et al., 2009; Cainelli et al., 2012). Interestingly, in our two green-industries and for

[22] *Pre-det size* has missing values for 66 companies, thus reducing the number of observations to 117.

our CO2 reducing eco-innovations, this is not the case: the micro-mechanisms underlying outsourcing matter more than the meso-ones, and they generally limit to the case of tangibles the extent to which outsourcing can gain a favourable CO2 impact from innovating.

Our results are also quite robust to the weak instrument problem. Firstly, 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 Rel Size* (*Unionisation*) is positively (negatively) related to the outsourcing of tangibles. *Knowledge rel* and *Product rel* are both positively associated with the outsourcing of intangibles. The coefficient for social capital (*Social cap*) is not significant at the standard confidence levels. It is also apparent that the instruments behave as anticipated in our theoretical argumentation.

At the bottom of Table 5 we report the Kleinbergen & Paap statistical test from Baum et al. (2007) for a weak identification problem. This test records a value well below the critical value of 6.86, meaning that the two-step GMM estimator may actually be affected by a problem of weak instruments. As said, in order to rule out any bias in our results, we estimate an IV model via the LIML estimator (column 4 Table 5), which is more robust to weak instruments (Chao and Swanson, 2005). Our main results are unaffected by this new estimator, and this time the weak identification test is very close to the critical value of 2.6 (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.

[INSERT TABLE 5 ABOUT HERE]

4.2.2 Sample selection

In order to account for 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 more likely to impact on internal green R&D activities (see Section 3.3). We thus use: firm size (*Log Employees*), motivations linked to existing environmental regulations (*Env regulations*) and to the availability of government financial incentives (*Env financial incentives*), internal procedures in place to regularly identify and reduce firm environmental impacts (*Env practices*), 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 if the firm has acquired new knowledge from public research centres in the period 2006-2010 (*U-I Collab*). This restriction is consistent with theoretically supported evidence on the pivotal content of basic, academically related, research in R&D activities for green innovation projects in general, and by that on the applied nature of the knowledge through which EICO2 take form (Rennings et al., 2013).

Column 2 of Table 6 presents the empirical estimates for the sample selection model that confirm our basic results. The selection equation (Column 1), instead, shows a positive correlation (at the 10% level of significance) between *Outsourcing of intangibles* and *Green R&D*, supporting the complementarity argument that firms which outsource intangibles are more likely to conduct internal green R&D (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*.

[INSERT TABLE 6 ABOUT HERE]

5 Concluding remarks

In order to extend knowledge about the drivers of eco-innovations, in this paper we have brought a typical industrial organisation issue, namely outsourcing, into the ecological realm. Although the importance of outsourcing for standard innovations has been widely shown, its significance for eco-innovations has to date been neglected. As a first step in this direction, in our analysis we confined this extension to two green sectors – photovoltaics and green construction – which are particularly crucial for attaining the environmental targets currently set on the international agenda for sustainable development. We focused on those specific eco-innovations which firms perceive as yielding results on the most urgent of these targets, namely a reduction in their CO2 footprints. With respect to this particular setting, we benefited from an original source of information that, with respect to a specific geographical area of local production systems (i.e. North-East Italy), is able to provide direct information on firms' recourse to outsourcing, otherwise captured in an indirect way, and to combine it with other information on their eco-innovative performances and structural features.

In the absence of a specific stream of studies on this issue, we have drawn on the extant literature at the crossroads between ecological and innovation studies, and put forward some exploratory hypotheses. These were empirically tested to obtain some first insights on the basis of which to develop a more precise body of arguments in the near future. In particular, in building these hypotheses we have placed particular emphasis on both the kind of sectors/regimes in which the outsourcing firms operate and the kinds of activities that they externalise.

The empirical application supports the importance of these two aspects. On the one hand, the technological regimes of the green sectors investigated seem to induce firms to behave in such a way as to counterbalance the possible impact of outsourcing on an eco-innovation, i.e. EICO2, which is still non-radical and thus potentially open to outsourcing's positive effects. On the other hand, the propensity to EICO2-innovate increases only with the externalisation of tangible activities, while that of intangibles even decreases it. This is an extremely interesting result which confirms, also in the green realm, the strategic importance of intangible assets (R&D, human capital, and the like) for eco-innovating.

These results have interesting strategic and policy implications. On the one hand, they show that strategic decisions about the firm's boundaries may have an environmental impact through the EICO2 innovation concerned, even without passing through the mechanisms of the famous PHH hypothesis. EICO2 may be sensitive to a simple re-organisation of labour across the boundaries of the firm and of its local (national) environment. On the other hand, some apparently unrelated industrial policies (e.g. trust and competition policies) may have important implications and act also as indirect instruments of environmental policy. Last, but not least, both actions require managers and policy-makers to handle intangibles with care, even when the attempt to free resources through their externalisation may be inspired by the search for a CO2 impact.

Finally, we acknowledge that the paper is of course not free of limitations. Apart from the specificity of the results, and from the need to replicate the analysis in different contexts in order to have general conclusions, the most important limitation is represented by the cross-sectional nature of our dataset, which prevents us from presenting our results as more than significant correlations among variables. Another major limitation is represented by the relationship between our focal variable, i.e. EICO2, and the CO2 footprint of firms, which we have been able to capture only in a subjective, perceived way. Similarly, our focal regressors about outsourcing suffer from the lack of information about the location of the providers, in particular within or outside the domestic boundaries. On the other hand, these and other possible limitations are the inevitable price to pay for the rich set of information that we have for nearly 200 companies. Furthermore, the same limitations are counterbalanced by a quite sophisticated set of controls in the econometric estimates, which make us confident that we have obtained reliable results on which to develop future research on the topic.

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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	21.43	0.2
Outsourcing Tang	26.67	14.29	0.05**
Outsourcing Intang	13.33	15.71	0.45
Observations	45	140	

** $p < 0.05$. 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=185)

	Mean	Median	Std. Dev.	Min	Max
Dependent variable					
EICO2	0.243	0	0.432	0	1
Explanatory variables					
Outsourcing	0.232	0	0.424	0	1
Outsourcing Tang	0.173	0	0.379	0	1
Outsourcing Intang	0.151	0	0.359	0	1
Controls					
Green R&D	0.519	1	0.501	0	1
Env regulations	0.357	0	0.480	0	1
Env financial incentives	0.243	0	0.430	0	1
Env practices	0.308	0	0.463	0	1
Age*	16.341	11	15.504	1	121
Employees*	16.268	6	42.929	0	433.6
Share Export Sales*	8.924	0	20.319	0	100
Group	0.114	0	0.318	0	1
Geographical controls					
Emilia-Romagna	0.243	0	0.430	0	1
Friuli Venezia Giulia	0.157	0	0.365	0	1
Trentino Alto Adige	0.184	0	0.388	0	1
Veneto	0.416	0	0.494	0	1

Asterisked variables have been reported without natural log transformation for ease of interpretation. All variables, with the exception of the Geographical controls, are firm-level measures..

Table 3: Correlational table

		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
[1]	*Outsourcing Tang*	1								
[2]	*Outsourcing Intang*	0.445	1							
[3]	*Green R&D*	0.097	0.226	1						
[4]	*Env regulations*	-0.012	0.032	0.311	1					
[5]	*Env financial incentives*	0.074	0.112	0.294	0.446	1				
[6]	*Env practices*	0.035	0.110	0.338	0.187	0.304	1			
[7]	*Log Age*	-0.074	-0.160	0.010	-0.065	-0.141	0.077	1		
[8]	*Log Employees*	0.017	-0.030	0.321	0.209	0.137	0.239	0.491	1	
[9]	*Log Share Export Sales*	0.022	0.045	0.050	0.150	0.155	0.076	-0.067	-0.008	1
[10]	*Group*	-0.029	0.087	0.038	0.125	0.155	0.130	-0.184	-0.044	0.144

Table 4: Probability of introducing an EICO2

	[1]	[2]	[3]	[4]
Outsourcing	0.3312			
	[0.5070]			
Outsourcing Tang		1.0008*		1.8322***
		[0.5554]		[0.5874]
Outsourcing Intang			-1.1340*	-2.2044***
			[0.6206]	[0.7261]
Green R&D	1.7398***	1.7679***	1.8944***	2.0997***
	[0.5720]	[0.6045]	[0.5490]	[0.6652]
Env regulations	1.8085***	1.9063***	1.7463***	1.8759***
	[0.5078]	[0.5344]	[0.4921]	[0.5376]
Env financial incentives	1.4545**	1.4468**	1.5622***	1.6866***
	[0.5733]	[0.5876]	[0.5790]	[0.6143]
Env practices	-0.8482*	-0.8578*	-0.8500	-1.0386*
	[0.5101]	[0.5103]	[0.5183]	[0.5649]
Log Age	-0.0319	0.0209	-0.1003	-0.0748
	[0.2894]	[0.2821]	[0.2891]	[0.2767]
Log Employees	-0.0713	-0.1094	-0.0781	-0.1682
	[0.2033]	[0.2010]	[0.2098]	[0.2077]
Log Share Export Sales	0.3412**	0.3489**	0.3575**	0.3887***
	[0.1431]	[0.1459]	[0.1419]	[0.1468]
Group	-0.4745	-0.4385	-0.3886	-0.0657
	[0.6968]	[0.6903]	[0.6386]	[0.6631]
Log-likelihood	-66.8367	-65.4609	-65.5248	-61.5065
McFadden's R^2	0.3488	0.3622	0.3616	0.4007
Wald χ^2	57.17[12]***	53.99[12]***	57.65[12]***	54.78[13]***
Observations	185	185	185	185

∗ $p < 0.1$, ∗∗ $p < 0.05$, ∗∗∗ $p < 0.01$. The dependent variable is the probability of eco-innovating in terms of CO2 emissions abatement. Robust standard errors and degrees of freedom are in parentheses. Identical results are obtained for column [2] when *Outsourcing* is measured as a count variable better to 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			0.6276***	0.7021***
			[0.2291]	[0.2705]
Outsourcing Intang			-0.9043***	-0.9890***
			[0.3255]	[0.3795]
Knowledge rel	0.1584	0.2587**		
	[0.0998]	[0.1065]		
Product rel	0.2012*	0.1890*		
	[0.1130]	[0.1068]		
Social Capital	-0.0950	0.0642		
	[0.0609]	[0.0534]		
Pre-det Rel Size	0.1309***	-0.0029		
	[0.0441]	[0.0374]		
Unionization	-1.4721**	-0.4357		
	[0.7349]	[0.6852]		
Green R&D	0.0592	0.0225	0.2537***	0.2556***
	[0.0748]	[0.0762]	[0.0809]	[0.0844]
Env regulations	-0.1191	-0.0301	0.2390***	0.2441***
	[0.0761]	[0.0772]	[0.0901]	[0.0926]
Env financial incentives	0.0189	-0.0278	0.2611**	0.2564**
	[0.1019]	[0.0983]	[0.1126]	[0.1155]
Env practices	0.0070	0.0997	-0.0188	-0.0116
	[0.0747]	[0.0825]	[0.0865]	[0.0921]
Log Age	0.0088	0.0024	-0.0642	-0.0694
	[0.0502]	[0.0657]	[0.0593]	[0.0631]
Log Employees	-0.0387	-0.0104	-0.0158	-0.0198
	[0.0490]	[0.0368]	[0.0379]	[0.0409]
Log Share Export Sales	-0.0263	-0.0053	0.0678***	0.0693***
	[0.0222]	[0.0238]	[0.0250]	[0.0258]
Group	0.0472	0.1817	0.2338*	0.2440*
	[0.1113]	[0.1465]	[0.1287]	[0.1365]
Geographical dummies	Inc.	Inc.	Inc.	Inc.
Hansen J test			2.478[3]	2.3494[3]
Endogeneity test			7.0676[2]**	
Kleibergen & Paap F test			2.3187	
Observations	118	118	118	

* 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 Kleinbergen & Paap see Baum et al. (2007). The Sargan-Hansen test of overidentifying restrictions is reported. Robust standard errors and degrees of freedom are in parentheses. *Pre-det Rel size* has missing values for 65 companies, thus reducing the number of observations to 118 compared to other estimates.

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Table 6: Sample selection - Heckman probit

	Selection equation	**Outcome equation**
	[1]	[2]
Outsourcing Tang	0.1108	0.9651**
	[0.3240]	[0.3870]
Outsourcing Intang	0.9541**	-1.0051**
	[0.4653]	[0.4385]
U-I collab	0.5226*	
	[0.2681]	
Env regulations	0.2282	0.6293**
	[0.2520]	[0.3119]
Env financial incentives	0.5367*	0.7780***
	[0.2929]	[0.2952]
Env practices	0.9150***	-1.0150***
	[0.2836]	[0.3313]
Log Age		-0.0234
		[0.1829]
Log Employees	0.3694***	-0.1392
	[0.0904]	[0.1345]
Log Share Export Sales		0.1321*
		[0.0772]
Group		-0.1414
		[0.3607]
Geographical dummies	Inc.	Inc.
Log-likelihood	-122.5564	
Wald χ^2 test of indep. eq. (ρ=0)	1274.58[1]***	
Observations	185	

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