European Commission

Policy Brief

The "green-impact" of the open innovation mode.

Bridging knowledge sourcing and absorptive capacity for environmental innovations

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Summary

This policy brief presents recent results on the impact that an open innovation mode has on European firms' environmental innovations. New evidence drawn from the CIS suggests that knowledge sourcing can increase the environmental innovation performance of firms. However, the way firms search for external knowledge and work to absorb it can lead them to different results, depending on whether they are involved in the adoption of an eco-innovation or the extension of their eco-innovation portfolio. Drawing on these results, policy implications for the European Research and Innovation Agenda are discussed.

1. Introduction

A sustainable kind of growth is among the priorities of the Europe 2020 Strategy, above all in environmental terms (EC, 2010). Not only is increasing resource efficiency necessary for current generations not to deprive future ones of development opportunities; it is also key to generating new growth and job opportunities in Europe through the introduction of new products (e.g. low environmental impact cars) and production processes (e.g. ICT aided shorter-time production cycles) that can boost its productivity and/or cut down its costs. The actions that the *Resource-Efficient Europe*

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Flagship Initiative (EC, 2011) foresees in this last respect – e.g. for climate change, energy, transport, industry, raw materials, agriculture, fisheries, biodiversity and regional development – and the EC's more recent commitment to promoting the adoption of *Advanced Manufacturing for Clean Production* (EC, 2012, p. 8) – e.g. low carbon intensive processes – are intended to exploit these opportunities and to provide the business sector with incentives and capabilities to grow sustainably.

Public support to firms' *environmental innovations* is one of the policy measurements through which a sustainable kind of growth can be promoted. Indeed, these are innovations in which firms introduce "a *product, production process, service or management or business method that is novel to [them] [...] and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives*" (Kemp and Pontoglio, 2007, p. 10). Classical examples are, among others, innovations that entail: reduced use of material and energy per unit of production output; reduced CO_2 'footprint' and reduced air, water, soil or noise pollution; after-sales use of a good or service and improved recycling of products after use.

However, supporting environmental innovations is not an easy task, given their specificities with respect to more "standard" innovations (Rehfeld *et al.*, 2007; Kemp and Pontoglio, 2007; Horbach, 2008).[1] Environmental innovations are relatively more subject to legislations and regulatory drivers. Accordingly, institutional interventions offer significant policy leverage for their adoption (one may just think of the role of environmental standards and emissions markets). Environmental innovations are also affected by a more systemic interplay between a "technology-push" – e.g. scientific discoveries in energy use/production and in recycling methods – and a "demand-pull", e.g. diffusion of socially responsible practices and adoption of sustainable supply-chains. Solving classical market failures – like private under-investments in (green) R&D – is thus as urgent for these innovations as addressing less standard ones, such as shaping sustainable consumer preferences and business/production modes. Last but not least, possibly more than standard innovations, environmental ones require firms to go beyond their existing industrial knowledge base and explore new external knowledge sources, even far from it.[2] Sourcing knowledge from specialised suppliers like KIBS, research institutions, and universities, and cooperating in R&D and innovation *wi*th key business partners, especially providers, is as important as developing innovation efforts internally (De Marchi and Grandinetti, 2013; De Marchi, 2012; Cainelli *et al.*, 2012). In other words, and especially with respect to environmental innovations, firms are reliant on an *open innovation mode*, in which the knowledge boundaries between them and the external environment become permeable (Chesbrough, 2003, 2006).

The extent to which environmental innovations can benefit from an open innovation mode is also an important policy

[1] In spite of their differences, environmental and non-environmental innovations should not be treated in a dichotomic way. On the contrary, while the former are also technological to a certain extent, important complementarities could exist between the two typologies, whose impact has only recently started to be addressed (Gilli *et al.*, 2013).

[2] One may consider the need to obtain scientific knowledge about the materials to be used (from universities and research institutes), the environmental standards to respect (from specific agencies), and the availability of sustainable production inputs (from the suppliers), to mention a few elements.

issue. In particular, policy makers should intervene in order to remedy the barriers that hamper the green impact of the open mode. These barriers are a typical example of a "system failure" in innovation (Metcalfe, 1995) and are linked to inefficient behaviours that firms might adopt both in interacting with external partners and in managing the diffusion of their knowledge internally (Georghiou and Clarysse, 2006). The lack of a proper network capacity and that of sufficient cognitive capabilities, respectively, are the most relevant of these barriers (Antonioli et al., 2012).

This kind of policy intervention of course requires a deep understanding of the "open environmental innovation mode". First of all, policy makers need to understand which mechanisms affect its outcomes. In particular, evidence is required to ascertain whether "any" kind of open innovation mode can have an impact, or whether its viability is rather affected by the way firms interact externally. Furthermore, the mechanisms that most enable firms to absorb external knowledge for the sake of their environmental innovations also merit attention. Last but not least, whether the open innovation mode is more a way for firms to enter into the green realm by eco-innovating "from scratch", or to increase their presence in it by extending their portfolio of environmental innovations, is important for identifying the most sensitive recipients of the relative policies.[3]

In order to fill such a wide knowledge gap, this policy brief presents and discusses some results that have recently been obtained at the European level on the green impact of the open innovation mode.[4] Section 2 briefly illustrates two pillars of the open innovation mode that merit scrutiny. Section 3 presents some empirical evidence on their functioning for EU firms. Section 4 concludes by drawing a number of policy implications.

2. "Open Environmental Innovation": Sourcing and Absorbing external knowledge

Academic research has largely shown that, with respect to technological innovations, the open innovation mode is of crucial importance in the current economic and business scenario (Laursen and Salter, 2006; Henkel, 2006). Among others, it can alleviate the burden of innovation investments, especially by SMEs, and it can help firms overcome the trade-off between innovation appropriability and innovation diffusion. Policy makers have fully endorsed this point, both within and outside Europe, and translated it into concrete policy measures (e.g. the Innovation Union Flagship). However, whether open innovation could also work for environmental innovations, along with its implications for firms' R&D, have not been fully researched yet.

Two issues in particular merit further attention: i) the way firms search for external knowledge related to their environmental innovations, that is, their knowledge sourcing; ii) their capacity to assimilate this external knowledge and combine it with internal knowledge, that is, their absorptive capacity.

i) Knowledge sourcing. The way firms search for external knowledge is an important pillar

[3] Although outside the scope of this brief, a further crucial issue to consider is the specific kind of environmental innovation – e.g. reducing CO_2 rather than wastes – that is most affected by the open innovation mode. While this kind of analysis is the most relevant for environmental studies and policies, the generic analyses that are addressed here remain relevant for innovation analyses.

[4] In particular, the policy brief draws on Ghisetti *et al.* (2013), where theoretical and methodological issues are illustrated more extensively.

of their open innovation (Laursen and Salter, 2006). The array of sources (e.g. business partners and/or public research organisations) from which firms draw in accessing external knowledge – the BREADTH of their knowledge sourcing – can enable them to tap into a variety of information signals and competencies. If properly controlled, their combination could increase the firm's innovativeness. Similarly, the intensity (i.e. number of interactions) with which firms draw on external knowledge providers – the DEPTH of their knowledge sourcing – can make them more innovative too. Through sustained interaction with each of the different possible sources of knowledge, firms are able to share feedback with them, mutually adapt their understanding and reach actual assimilation of external knowledge.

These two openness traits of a firm's knowledge-sourcing have been found to impact on its technological innovations (e.g. new products and/or processes) (Laursen and Salter, 2006). Given their specificities and systemic nature, an impact is also expected for its environmental innovations. However, the same features have also proven to impact on technological innovations only up to a certain extent, after which open relationships can become cumbersome to manage. Should this also prove the case for environmental innovations, policy makers will have to take this into account in supporting their adoption.

ii) Absorptive capacity. Open innovation would not work if firms did not have sufficient capacity to assimilate external knowledge and to exploit it in an innovative way (Cohen and Levinthal, 1989, p.569). Innovation studies have largely shown that, with respect to technological innovations, investments in R&D are a crucial factor contributing to this absorptive capacity. Through them, innovative firms reduce their cognitive distance with respect to external knowledge sources and understand them better (Lewin et al., 2011). More recent, but generally in support of technological innovations, is the evidence on the role in absorptive capacity played by "social integration mechanisms" within the firm (Zhara and George, 2002): organisational practices, such as cross-functional interfaces and formal communication flows across divisions, that favour the combination of external with internal knowledge and their transformation into actual innovation (Franco et al., 2012).

Are such absorptive mechanisms at work with respect to environmental innovations as well? On the one hand, this would be expected with respect to R&D. Indeed, its indirect innovative role – i.e. through the absorption of external knowledge – is usually taken to account for the non-significance of its direct role – i.e. through the introduction of new knowledge internally – in empirical studies (Cainelli et al., 2012). On the other hand, social integration mechanisms are also expected to be very important in enabling firms to absorb external knowledge for eco-innovating. Indeed, environmental innovations have a significant organisational component, which is manifested in the introduction of environmentally friendly business models and organisation modes (e.g. EMAS).

However, the risk also exists that investments in R&D and in organisational practices that facilitate the absorption of external, environmental knowledge could divert cognitive and managerial resources from the open innovation mode. This is another relevant issue policy-makers should retain in evaluating the direct and indirect impacts of supporting schemes for R&D and other kinds of intangible capital.

3. Does open innovation increase environmental innovation performances? Empirical evidence on 11 European countries

Empirical evidence on the issue at stake can be obtained by drawing on the "environmental section" of the Community Innovation Survey (CIS) 2006-2008 and looking at the different types of environmental innovations that the surveyed firms have adopted[5]: 9 typologies, among which end-of-pipe, cleaner production technologies and innovations related to the introduction of new products (see the legend of Figure 1 for details).

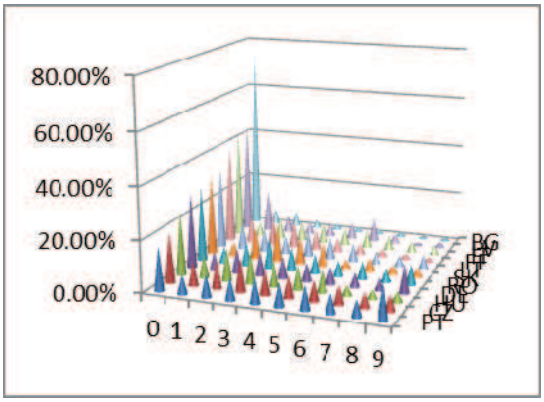
As the 0-line of Figure 1 shows, the percentage of surveyed firms that have introduced at least one of these innovations (the complement to 1 of the 0 typology) in the observed period is quite variable across the countries considered: from 26%, in Bulgaria (BG), to more than 80% in Portugal (PT), and around half of the surveyed firms in Latvia (LV) (55%) and Italy (IT) (57%).

The firm's propensity/capacity to enter into the green-side of the innovation realm – from whatever "door" (kind of innovation) – appears heterogeneous across the investigated European countries. As we said, whether the open innovation mode partially accounts for this is a first important result to provide to policymakers.

As Figure 1 shows, cross-country differences also emerge by looking at the percentages of firms that have introduced different numbers of the 9 typologies of environmental innovations: in Portugal (PT), for example, the share of firms that have introduced as many as 9 typologies exceeds 10% of the total, while it is lower for lower numbers. In Hungary (HU), on the other hand, the distribution is relatively more homogeneous, with more than 10% of the firms having introduced 2, 3 or 4 typologies of innovation.

In brief, the propensity/capacity of environmental innovators to increase their portfolio of environmental innovations is also heterogeneous across the investigated European countries. Whether the open innovation mode has an impact on this extensive margin of environmental innovation is thus also relevant to address.

Fig. 1 Distribution of the number of environmental innovation typologies across countries (% of firms per number of EI)



Number of typologies of environmental innovations (from 0 to 9) out of the following: none; reduced material use per unit of output; reduced energy use per unit of output; reduced CO2 'footprint' (total CO2 production); replaced materials with less polluting or hazardous substitutes; reduced soil, water, noise, or air pollution and recycled waste, water, or materials; after-sales use of a good or service; reduced energy use; reduced air, water, soil or noise pollution; improved recycling of product after use.

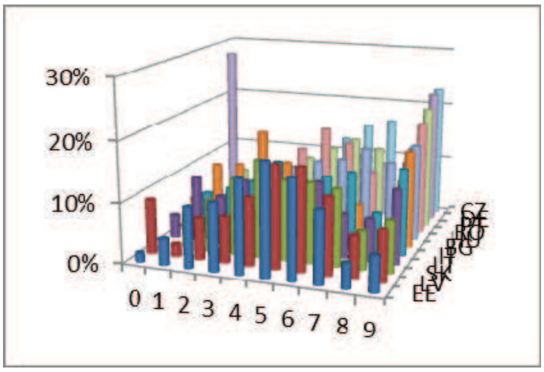
Significant differences among the investigated European companies also emerge from the analysis of the BREADTH and DEPTH of their knowledge sourcing, as well as of their involvement in R&D and of their social integration mechanisms.[6]

[5] This evidence refers to anonymised micro-data provided by Eurostat for the manufacturing firms of the following 11 countries: Bulgaria, Czech Republic, Germany, Estonia, Hungary, Italy, Lithuania, Latvia, Portugal, Romania and Slovakia. For a more detailed description, see Ghisetti *et al.* (2013).

[6] *BREADTH* can be defined as the number of external information sources the firm relies upon for its innovation activities out of the list of 9 potential knowledge providers (see Figure 2). *DEPTH* counts the number of these external information sources to which the firm attributes a "high" degree of importance, among the four listed options (not used, low, medium, high importance). A dummy, *RD*, captures whether the firm performs internal R&D investments. Social integration mechanisms are also captured by a dummy, *SIM*, by looking at the importance that firms attribute to

As far as the traits of knowledge sourcing are concerned, we can observe that, in nearly all the countries, the distribution of the number of external sources (from 0 to 9) used for eco-innovating shows a normal-like distribution: as expected, in every country, the BREADTH of knowledge sourcing for the majority of the firms is at an intermediate level (between 4 and 5), with fewer firms sourcing from a smaller and larger number of providers (Figure 2). However, we can also observe that in certain countries, e.g. Czech Republic (CZ), with an apparently better eco-performance, the greatest share of firms (in CZ 23%) source knowledge from as many as 9 providers. In some other countries, such as Latvia (LV), the number of firms with a nil knowledge BREADTH is non-negligible (in LV, more than 4%).

Figure 2 – Distribution of BREADTH across countries (% of firms per number of external information sources)

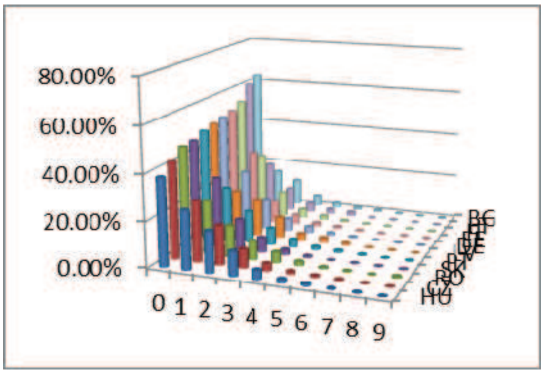


Number (from 0 to 9) of external information sources the firms rely upon out of the following: none; suppliers; customers; competitors; consultants and private R&D institutes; universities; government or public research institutes; conferences, trade fairs, exhibitions; scientific journals and trade/technical publications; professional and industry associations.

Interesting differences also emerge by looking at the country distribution of the DEPTH of knowledge sourcing (Figure 3). As expected, in all the investigated European countries, the majority of the firms interact deeply with few providers (no more than 3). Nevertheless, differences across countries do emerge, in particular in the percentage of firms that rely on 2 information sources: from less than 10% in Estonia (EE), to more than 18% in Hungary (HU).

those internal information channels/flows into which external ones will possibly circulate to be absorbed (on this, see Fosfuri and Tribò, 2008).

Figure 3 – Distribution of DEPTH across countries (% of firms per number of information sources)



Number of external information sources (from 0 to 9) to which firms attribute a high degree of importance.

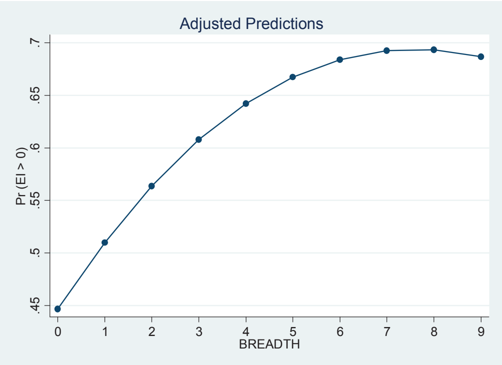
By crossing this last bit of evidence with the previous one on the environmental innovation performances of firms in Europe, econometric estimates provide results in support of an open environmental innovation mode (see the Technical Annex, Note 1, for the adopted methodology). However, important specifications emerge when we look at the two aspects at work – that is, the probability of eco-innovating and that of enlarging the portfolio of environmental innovations – with some interesting policy implications.

The probability of eco-innovating

The wider the array of knowledge sources firms draw on, the more probable the introduction of an EI: as expected, BREADTH increases the firm's coverage of the multiple knowledge needs entailed by the multi-dimensionality of environmental innovations (Tab.1, Column I). The probability of being an environmental innovator also increases with the competences that the firm acquires through deep interaction with its external knowledge providers (DEPTH). By becoming more intensive, such interaction transforms a spot-like knowledge exchange into learning-by-interacting for the sake of EI (Tab.1, Column I).

However, an important caveat should be noted for BREADTH (Tab.1, Column II). As Figure 4 also shows, while some knowledge variety is required in order to step into the environmental innovation realm, broadening its external search over a certain level makes the firm less prompt, if not even more reluctant, to introduce an EI.[7] This result suggests that open innovation could expose the firm to redundant and/or inconsistent information signals, and, as we will say, has important policy implications.

Fig. 4 Curvilinear effect of BREADTH on the predicted EI-probability



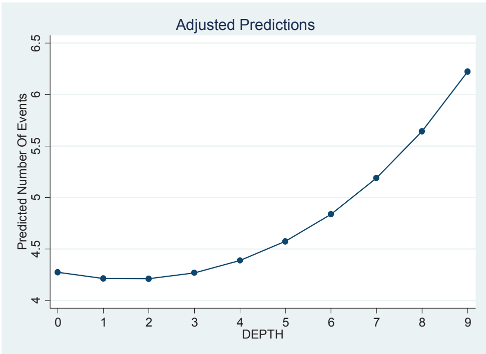
Interesting results also emerge from the analysis of the role that the firm's absorptive capacity has on their probability to eco-innovate. As expected, R&D positively moderates the impact of BREADTH on this probability, and actually helps the firm to scan and master external knowledge (Tab.1, Column III). However, this does not occur for DEPTH, which is negatively moderated by R&D (Tab.1, Column III). This means that when R&D investments are in place, possibly within an ad-hoc division in the firm, establishing deep external interactions represents an obstacle to the decision to eco-innovate. Similar "negative" results hold true for the role of social integration mechanisms, but this time only with respect to BREADTH (Tab.1, Column IV). These social integration mechanisms actually work on the adoption of environmental innovations only indirectly, through the socialisation of external knowledge.

Overall, these important results reflect possible knowledge mismatches and managerial overloading in dealing with both internal and external knowledge.

The portfolio of environmental innovations

Knowledge sourcing also helps environmental innovators to deal with the different realms (e.g. energy, materials, CO2) that different environmental innovations entail (Tab.2, Column I). However, important differences and policy implications emerge with respect to potential eco-innovators. First of all, the constraints on the impact of BREADTH now disappear (Tab.2, Column II). In the attempt to enlarge the portfolio of this family of innovations with other types that are different but can still benefit from the firm's "environmental knowledge baseline", the risk of redundant and/or conflicting insights can be more easily accommodated. Furthermore, environmental innovators get increasing returns from DEPTH (Tab.2, Column II). As Figure 5 also shows, negative marginal returns only accrue for firms with no deep interactions, while marginal effects not significantly different from zero are in place only for firms with few profound interactions (i.e. 1 or 2).[8]

Fig. 5 Curvilinear effect of DEPTH on the predicted number of EI-typologies



This is a rather interesting result, especially if one considers the risks of lock-in that sustained and repeated external interaction with partners in innovation could potentially entail.

In other words, by the very fact of being eco-innovators, firms seem to have open

[7] On this point, see Technical Annex, Note 2.

[8] On this point, see Note 3 in the Technical Annex

innovation capabilities that potential eco-innovators do not have.

This result can also explain the effects that the antecedents of the firm's absorptive capacity have on the number of environmental typologies that eco-innovators introduce (Tab.2, Column IV). Unlike potential innovators, actual innovators do not benefit (in extending their EI portfolio) from an additional BREADTH impact when they also invest in R&D. Instead, deeply sourced external knowledge (DEPTH) appears to conflict with that developed internally through R&D. All in all, the trade-off between the engagement in internal and external knowledge-based activities is confirmed and emerges as a general result of the evidence at stake. However, an exception to that is now emerging with respect to the role of social integration mechanisms. Unlike potential eco-innovators, for actual innovators these organisational mechanisms do not clash with the intensity of external knowledge relationships, although they do not enhance them either. Furthermore, rather than simply reinforcing the impact of diverse external knowledge inputs (BREADTH), this time organisational mechanisms for knowledge socialisation appear necessary for a broad sourcing strategy to allow the firm to eco-innovate more extensively.

4. Conclusions and policy implications

Both knowledge sourcing and absorptive capacity are extremely relevant for the firm's capacity to eco-innovate and to extend its portfolio of eco-innovations. Overall, the evidence is in favour of an open environmental innovation mode and leads to a first policy implication:

Policy implication 1: Firms benefit from an open innovation mode in order to become eco-innovators. Favouring knowledge exchanges and networking among firms and other organisations could have a significant impact on companies' contribution to a sustainable kind of growth in Europe and adoption of clean production methods in manufacturing in particular.

However, evidence also shows that policy support to an open environmental innovation mode should not be unconditional. On the one hand, the *BREADTH* of firms' knowledge sourcing can become a problem for potential new eco-innovators:

Policy implication 2: Firms' propensity to eco-innovate decreases when, in order to do so, they excessively increase the openness of their knowledge sourcing. Policy support to innovation cooperation in the field (e.g. to R&D partnerships and technology transfer for environmental innovations) could be conditioned by the size of the relevant network. Green-knowledge platforms, for example in specific manufacturing sectors or regional contexts, should not be too widely promoted and possibly delimited to relevant communities of practitioners.

On the other hand, the cognitive and organisational efforts required by *deep* knowledge sourcing could conflict with that required by its internal assimilation:

Policy implication 3: With respect to the decision to eco-innovate, a trade-off emerges between the firm's engagement in creating and exploiting internal knowledge through R&D and organisational investments and its engagement in stable (deep) external relationships. R&D-supporting policies to environmental innovations should carefully take into account this trade-off and the possible crowding out it could entail on the firm's capacity to interact deeply with external knowledge providers.

Additional evidence with policy-relevant implications emerges by looking at the environmental innovations portfolio of existing eco-innovators in Europe. In general, the constraints referred to earlier with respect to new potential eco-innovators are attenuated in this case, showing the importance of having an environmental knowledge base for expanding eco-innovation activities:

Policy implication 4: Eco-innovators benefit from knowledge sourcing unconditionally, when they try to enlarge their portfolio of environmental innovations. Policy support to knowledge interactions could be expected to enable these firms to become more widely eco-innovative, especially by providing them with incentives to consolidate successful partnerships.

In particular, previous experience of environmental innovations also helps in avoiding the trade-off that the "new" eco-innovators face between the open and the standard modes of innovating, that is, between the *DEPTH* of their knowledge sourcing and the functioning of their social integration mechanisms: while the latter does not moderate the former, they do not clash either. This evidence bears interesting policy implications with respect to the effect of social integration mechanisms for eco-innovators.

Policy implication 5: The experience of environmental knowledge that eco-innovators enjoy partially attenuates the trade-off between an inward and outward oriented environmental innovation mode. Policy support to internal organisational innovations which help external knowledge to circulate within the firm (e.g. ICT based governance modes) could be helpful for eco-innovators to turn a variety of knowledge sources into a variety of environmental innovations.

All in all, although an open innovation mode seems to have positive effects on companies' efforts to enter into and develop the portfolio of their environmental innovations, a better understanding of its inner mechanisms can be useful. Further analysis in this direction could help to make policy interventions more targeted and effective.

Table 1 - Factors explaining the EI-probability

Variables	(I)	(II)	(III)	(IV)
BREADTH	0.0984***	0.271***	0.263***	0.255***
	(0.00835)	(0.0288)	(0.0290)	(0.0293)
DEPTH	0.0664***	0.0976***	0.137***	0.182***
	(0.0186)	(0.0358)	(0.0379)	(0.0509)
BREADTH^2		-0.0177***	-0.0181***	-0.0196***
		(0.00281)	(0.00290)	(0.00303)
DEPTH^2		-0.00744	-0.00551	-0.00443
		(0.00767)	(0.00715)	(0.00774)
BREADTH*RD			0.0337*	
			(0.0181)	
DEPTH*RD			-0.109***	
			(0.0350)	
BREADTH*SIM				0.0486**
				(0.0191)
DEPTH*SIM				-0.119**
				(0.0486)
POLSTR	0.00638	0.00718	0.00700	0.00689
	(0.0236)	(0.0236)	(0.0236)	(0.0237)
COOP	0.439***	0.442***	0.441***	0.441***
	(0.0549)	(0.0551)	(0.0552)	(0.0551)
SIM	0.256***	0.210***	0.207***	0.0730
	(0.0479)	(0.0489)	(0.0491)	(0.0939)
RD	0.345***	0.324***	0.242**	0.323***
	(0.0471)	(0.0475)	(0.105)	(0.0475)
lnTURNOVER	0.0192***	0.0203***	0.0201***	0.0201***
	(0.00689)	(0.00692)	(0.00692)	(0.00693)
MNC	0.171***	0.185***	0.181***	0.184***
	(0.0627)	(0.0628)	(0.0629)	(0.0629)
EXPORT	0.252***	0.250***	0.248***	0.248***
	(0.0471)	(0.0472)	(0.0473)	(0.0473)
...	0.126**	0.130**	0.129**	0.129**
	(0.0536)	(0.0537)	(0.0538)	(0.0538)
Country Dummies	YES	YES	YES	YES
Sector Dummies	YES	YES	YES	YES
Constant	-0.631***	-0.922***	-0.902***	-0.865***
	(0.138)	(0.147)	(0.148)	(0.150)
Observations	14.366	14.366	14.366	14.366
Prob > Chi^2	0.00	0.00	0.00	0.00
McFadden Adj. R^2	0.167	0.169	0.170	0.170
Log PseudoL	- 7945.0505	-7922.8386	-7917.458	- 7917.7947

Table 2 - Factor explaining the number of EI-typologies (for EI innovators)

Variables	(I)	(II)	(III)	(IV)
BREADTH	0.0324***	0.0133	0.00946	0.0133
	(0.00308)	(0.0112)	(0.0113)	(0.0114)
DEPTH	0.0125***	-0.0217**	-0.00699	-0.0232
	(0.00481)	(0.00970)	(0.0113)	(0.0172)
BREADTH^2		0.00188*	0.00225**	0.000963
		(0.001000)	(0.00105)	(0.00112)
DEPTH^2		0.00704***	0.00702***	0.00712***
		(0.00169)	(0.00165)	(0.00169)
BREADTH*RD			-0.000839	
			(0.00612)	
DEPTH*RD			-0.0242***	
			(0.00935)	
BREADTH*SIM				0.0135*
				(0.00791)
DEPTH*SIM				0.000923
				(0.0161)
POLSTR	0.0142*	0.0141*	0.0140*	0.0141*
	(0.00824)	(0.00823)	(0.00823)	(0.00822)
COOP	0.0172	0.0164	0.0185	0.0158
	(0.0152)	(0.0152)	(0.0153)	(0.0152)
SIM	0.0391**	0.0488**	0.0453**	-0.0176
	(0.0189)	(0.0191)	(0.0192)	(0.0424)
RD	0.0943***	0.0989***	0.130***	0.0993***
	(0.0147)	(0.0147)	(0.0387)	(0.0148)
lnTURNOVER	0.0106***	0.0104***	0.0103***	0.0102***
	(0.00306)	(0.00304)	(0.00305)	(0.00304)
MNC	0.0885***	0.0878***	0.0874***	0.0880***
	(0.0173)	(0.0173)	(0.0173)	(0.0173)
EXPORT	-0.0430**	-0.0430**	-0.0431**	-0.0421**
	(0.0171)	(0.0171)	(0.0170)	(0.0170)
INNOPOL	0.0168	0.0148	0.0150	0.0149
	(0.0151)	(0.0151)	(0.0151)	(0.0151)
Country Dummies	YES	YES	YES	YES
Sector Dummies	YES	YES	YES	YES
Constant	1.153***	1.200***	1.195***	1.226***
	(0.0547)	(0.0594)	(0.0601)	(0.0610)
Obs count>0	8841	8841	8841	8841
McFadden Adj. R^2	0.3362	0.3365	0.3365	0.3364
Prob > Chi^2	0.00	0.00	0.00	0.00
Log PseudoL	- 19738.875	-19729.305	- 19725.928	- 19727.495

Variables description

Variable	Description
EI	Number of EIs introduced by firms
BREADTH	Number of external information sources the firms rely upon
DEPTH	Number of external information sources to which firms attribute a high degree of importance
COOP	R&D cooperation with cooperation partners (DUMMY)
EXPORT	Involvement in international markets (DUMMY)
INNOPOL	Existence of public support to firms' innovation activities (DUMMY)
lnTURNOVER	Natural logarithm of firms' turnover in 2006
MNC	Affiliation to a multi-national corporation (DUMMY)
POLSTR	Logarithm of country/sector CO_2 emission intensity in terms of Value Added in 2006
RD	Engagement in R&D activities (DUMMY)
SIM	Importance of the internal information flows for firms' innovation activities (DUMMY)

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TECHNICAL ANNEX

Methodological notes

Note 1. In order to analyse the two different processes of the firm's adoption of an *EI* and the environmental innovator's extension of the kinds of *EI*s, the dependent variable *EI* can be defined as the number of *EIs* introduced by the firm and a hurdle negative binomial model can be used. Following Cameron and Trivedi (1998), the estimates consist of a Logit part (Table 1) and of a zero-truncated negative binomial part (Table 2).

Note 2. Figure 4 presents the marginal effects function of *BREADTH*. The turning point is calculated by making the first derivative of the marginal effects function (estimated on the logit part of our hurdle model) equal to zero. The punctual estimation of the *BREADTH* value at which the function has a maximum (i.e. the first derivative equals zero) is 7.63. However, the first derivative is not significantly different from zero (at the 95% level) for values of *BREADTH* between 6.66 and 8.59. Hence, for values of *BREADTH* which are higher than 8.59, the function has a negative slope. Given the way *BREADTH* is created in our application (i.e. an integer number), null marginal effects are in place when *BREADTH* equals 7 or 8, while the presence of negative marginal effect is limited to cases in which *BREADTH* is at its maximum value (i.e. 9).

Note 3. Following Note 2, the punctual estimation of the *DEPTH* value at which the function has a minimum is 1.54. For *DEPTH* values between 0.74 and 2.33 marginal returns are not different from zero, while for values between 0 and 0.74 marginal effects are significantly negative. Hence, given the integer nature of *DEPTH*, it can be concluded that only when *DEPTH* equals 0 is there a negative return, while when *DEPTH* is 1 or 2 the marginal effects are zero.

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Abstract

This Policy Brief presents recent results on the impact that an open innovation mode has on European firms' environmental innovations. New evidence drawn from the CIS suggests that knowledge sourcing can increase the environmental innovation performance of firms. However, the way firms search for external knowledge and work to absorb it can lead them to different results, depending on whether they are involved in the adoption of an eco-innovation or the extension of their eco-innovation portfolio. Drawing on these results, policy implications for the European Research and Innovation Agenda are discussed.

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