OPENNESS AND SUSTAINABILITY IN COMPETITIVE RESEARCH GRANTS: PROJECT-LEVEL EVIDENCE FROM THE EU FP7

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Openness and sustainability in competitive research grants: project-level evidence from the EU FP7

Abstract

Research grants promoted by the European Union (EU) aims at fostering innovation and excellence science. Cooperation is recognized as a crucial means to achieve impactful innovation, as well as to disseminate knowledge to various actors of the society. As sustainability becomes the priority of the EU agenda, it is crucial to understand the factors underlying the success of research projects in environmental-related fields. This paper builds on the green open innovation literature, and by taking a project-level approach, it aims at understanding how open innovation is connected to impactful projects, and whether environmental related goals positively moderate the relation between openness and project impact measured as received funds and publications. This paper employs a dataset of 7,055 research projects under the Cooperation programme of the Seventh Framework Programme (FP7) in 2007-2013 funded by the EU. The results show that higher openness in terms of breadth is positively related to the funds received by the project, but it does not influence scientific output. Green projects (i.e. projects in energy, environmental, transportation and agriculture domains) are smaller on average; however, for green projects the relation between breadth and funds is steeper, suggesting that openness and environmental sustainability are strongly intertwined in more ambitious, complex and high-level projects. These results contribute to the literature on green open innovation at the project-level by providing novel evidence of how openness and environmental goals can increase knowledge creation and impact on the society. To practitioners, this paper suggests the necessity to tackle environmental challenges with a wider network of stakeholders.

Keywords: green open innovation; project-level; breadth; environment; FP7; EU

1 Introduction

There has been a huge acceleration in the European Union (EU) to sustain the transition to a greener Europe and to boost its industrial competitiveness. Sustainability has been part of the EU actions for decades and the creation of an excellent research base has always been one of the major goals of the various framework programmes (Colombo, Pansera, and Owen 2019; Veugelers et al. 2015). As the process towards a greener Europe accelerates with the latest ambitious EU agenda (e.g. the *European Green Deal* consists of one third of the 1.8 trillion euro investments from the *NextGenerationEU* Recovery Plan, and the EU's seven-year budget[i]), it is crucial to deepen our knowledge on how organizations embark on those innovations that reduce the impact of economic activities on the natural environment, the so-called *green innovation* (Bocken et al. 2014; Bogers, Chesbrough, and Strand 2020; Porter and Kramer 2019)

Green innovation differs from general innovation for the stronger role of regulation and external stakeholders (e.g. consumers, government, NGOs) (Orlando et al. 2020), and the more complex and risky process (Ghisetti, Marzucchi, and Montresor 2015; Hojnik and Ruzzier 2016). Hence, existing literature has long established that external collaborations are crucial in environmental fields and an open innovation approach has become very common in sustainability studies (Aquilani et al. 2020; Behnam, Cagliano, and Grijalvo 2018; Bogers, Chesbrough, and Strand 2020; D'Agostino 2021; 2020; González-Moreno, Triguero, and Sáez-Martínez 2019; Moreno-Mondéjar, Triguero, and Sáez-Martínez 2020; Muscio, Nardone, and Stasi 2017; Olsen, Sofka, and Grimpe 2017).

This recent and emerging field – i.e. green open innovation (GOI) – has mostly taken a firm-centric view, while neglecting other levels of analysis (D'Agostino 2020). Indeed, a more recent perspective in open innovation literature is to take a project-level approach to account for the fact that firms vary their mode of innovation across projects because innovation projects are heterogenous (e.g. in terms of complexity, team composition, strategic importance) and should be managed differently (Bagherzadeh, Markovic, and Bogers 2021; Cassiman, Di Guardo, and Valentini 2010; Du, Leten, and Vanhaverbeke 2014; Markovic et al. 2021; Marullo et al. 2020).

The project-level approach is particularly relevant for green innovation because environmental challenges may require a radical new way of doing old things, which may be translated in different ways green innovation projects are managed. For example, environmental challenges may require the use of new materials in old products, so that organizations may switch from a more closed-mode of innovation along familiar domains of technologies to more open approaches to discover more sustainable materials outside their traditional core-technologies. The story of the paper fiber bottle is a good example of that. Originally it was a project started by Carlsberg, the Danish beer manufacturer, and the small firm ecoXpac in 2010. In later stages, the project was supported by the Technical University of Denmark (DTU) and the Swedish packaging company BillerudKorsnäs. The project received financial support from the Danish innovation-funding organization (i.e. IFD) (Bogers, Chesbrough, and Strand 2020). In 2019, the fiber bottle becomes the key product of the startup Paboco, partnering with brands such as CocaCola, L'Oréal, and P&G[ii]. While Carlsberg was interested in developing a biodegradable bottle as part of its sustainability approach, packaging was not its core business, and it did not intend to differentiate vertically. The startup ecoXpac had the technology, but it needed the expertise of Carlberg on the technical requirements for bottling as well as its market knowledge and capacities (H. W. Chesbrough et al. 2018). The funds received by the IFD supported the improvement of the manufacturing process in collaboration with the university, especially in terms of reducing the energy consumption and testing different bottle designs. In addition, BillerudKorsnäs, which focused on fiber-based packaging, provided expertise on several technical problems arising with the fiber bottle and that ecoXpac lacked, and it was willing to provide funding to continue the research by investing directly in the startup. This example shows how radical innovation in bottle materials would have not been possible without the collaboration between an incumbent manufacturer and external actors. As discussed in Bogers et al. (2020), Carlsberg purposefully chose an open approach without nondisclosure and exclusivity agreements, differently to what typically required to its partners, because of the higher level of uncertainty and complexity, and to attract the larger number of partners to collaborate for creative solutions.

Despite a growing interest in whether environmental-related projects require more open approach, there is a lack of evidence on whether projects that combine openness and environmental sustainability are more successful. This paper contributes to the project-level literature on green open innovation (Chistov, Aramburu, and Carrillo-Hermosilla 2021; Olsen, Sofka, and Grimpe 2017) by providing evidence of whether a more open approach in terms of breadth of knowledge sources (Laursen and Salter 2006) is employed in more ambitious, complex and high-level projects – which are more impactful projects, and how environmental challenges coupled with openness contribute to achieve such projects. In this work, the term green is used interchangeably with environmental sustainability.

The paper is organized as follows. Section 2 presents the literature on open innovation at the project-level. Section 3 discusses the peculiarities of GOI. Section 4 develops the research questions. Section 5 and 6 describe the data and the variables, and Section 6 presents the methodology. The analysis is developed in Section 8 (descriptive analysis) and 9 (econometric analysis). Finally, Section 10 draws some conclusions.

2 Collaboration in research projects

The idea that the boundaries of the firms need to be permeable to the external environment is quite an established concept in innovation literature (H. W. Chesbrough 2003; Granstrand, Patel, and Pavitt 1997; von Hippel 1988). Different stakeholders are involved in these networks of innovators, e.g. private firms, research organizations, universities, public bodies, and financial institutions (Etzkowitz and Leydesdorff 2000; Iammarino 2005). Collaborations foster innovation, increase the competitive advantage of firms, and have positive effects on industries and societies (Laursen and Salter 2014; Rosenkopf and Nerkar 2001)

By collaborating, organizations may take different approaches across the projects they are involved, depending on the strategic interests they have, or the characteristics of individuals and teams involved, especially in the case of large organizations (Olsen, Sofka, and Grimpe 2017; Bagherzadeh, Markovic, and Bogers 2021). The outcome of a project is the result of the interactions within the network, often arising in a complex context (Crupi et al. 2021). Hence, taking a project perspective is crucial to understand what characteristics of the project influence the outcome.

Diversity of participants is one of the most crucial dimensions in collaborations (Laursen and Salter 2006), also at the project levels (Grimpe, Sofka, and Distel 2021; Nepelski, Van Roy, and Pesole 2019; Tang, Fisher, and Qualls 2021). Studies have highlighted that different organizations participating in EU-funded research grants have different motivations. Companies aim at accessing to new relevant knowledge, either to simply monitor the advancement of the technology or possibly to explore commercialization (Grimpe, Sofka, and Distel 2021; Nepelski, Van Roy, and Pesole 2019). Universities and research centres are less interested in the practical applications of the technologies, and more to the advancement of science. Public bodies are more interested in the implications of the new technologies for the society, while other institutions (e.g. NGOs, trade association etc) support the specific interests of their stakeholders.

The diversity of organizations participating in the research projects fosters innovation by offering wider solutions, multiple recombination of knowledge, and cross-fertilization. At the same time, projects with too diverse organizations may encounter coordination and communication problems.

3 Green open innovation (GOI)

GOI relates to innovations that reduce or eliminate the harmful impact of economic activities on the natural environment which are managed with an open approach (Berrone et al. 2013; Chen 2008; D'Agostino 2020; 2021). The open innovation paradigm which has recently involved environmental issues has been studied under different labels, such as open eco-innovation, sustainable open innovation, environmental innovation or GOI (Aquilani et al. 2020; Bogers, Chesbrough, and Strand 2020; D'Agostino 2020; Russo Spena and Di Paola 2020; Olsen, Sofka, and Grimpe 2017). However, beside the different terms, these studies have highlighted the role of cooperation, which is particularly important in environmental technologies for two main reasons (De Marchi 2012; Ghisetti, Marzucchi, and Montresor 2015; Horbach, Oltra, and Belin 2013). Firstly, there is greater institutional pressure from multiple stakeholders (Berrone et al. 2013), including governments and NGOs, and consumers (Ketata, Sofka, and Grimpe 2015). This implies that firms have a strong incentive to communicate effectively with these agents (Laperche and Picard 2013).

Secondly, green innovation manifests additional knowledge complexity and uncertainty (Ketata, Sofka, and Grimpe 2015), which may come from higher distance between old ways of doing things and new "green" products, from the heterogenous knowledge basis of green innovation (e.g. electric vehicles), and from the need to make radical organizational changes (skills, culture, business model) (Cainelli, Mazzanti, and Montresor 2012; Horbach, Oltra, and Belin 2013; Laperche and Picard 2013).

One of the most studied themes in GOI is the degree of openness measured through the 'breadth' of external collaboration (Bagherzadeh, Markovic, and Bogers 2021; Chistov, Aramburu, and Carrillo-Hermosilla 2021; D'Agostino 2020). Firms differ in their external search strategy. The most innovative firms tend to search widely and deeply, even though this 'openness' is subjected to decreasing returns (Laursen and Salter 2006).

4 Openness and environmental sustainability in research projects

The success criteria of projects vary depending on the type of projects (Shenhar et al. 2002). In the context of public-funded projects, policy makers aim at advancing the scientific base and supporting firms in their innovation efforts. This is pursued by fostering the combination of scientific and technological assets, and the creation of knowledge to be transferred across organizations, research groups, and countries (Du, Leten, and Vanhaverbeke 2014). Larger projects are more likely to play this role. Firstly, they are more complex, costly, interdisciplinary, and generate a critical mass in terms of knowledge that is more likely to be connected to excellent projects. Secondly, larger projects are expected to have a wider impact on the different groups of interests involved, such as individual researcher productivity (Defazio, Lockett, and Wright 2009). Therefore, larger projects are more likely to address high-level research and foster knowledge diffusion, so that the impact on the scientific and industrial base will be maximized.

There are different channels through which open innovation can benefit high-level, impactful research projects (Du, Leten, and Vanhaverbeke 2014; Kobarg, Stumpf-Wollersheim, and Welpe 2019; Salge et al. 2013). Multiple types of partners ensure that diverse perspectives are taken into account, so that the project results will impact a wide array of actors in the society. Openness can improve the innovativeness and quality of solutions that are developed in projects. The variety of knowledge stimulates novel associations, and provide distinct expertise (H. W. Chesbrough 2003;

Laursen and Salter 2006), thus leading to better solution that are more likely to be applied successful.

The relation between wider sources of knowledge and innovation has been often found as an inverse U-shaped (Ghisetti, Marzucchi, and Montresor 2015; Laursen and Salter 2006), meaning that too much openness can hinder the innovation process. At the project-level, Kobarg et al. (2019) find that breadth has an inverse U-shaped relation with the development of new technologies in German firms, but not with incremental innovation. Using health-care innovation projects, Sage at al. (2013) find an inverse U-shaped relation between breadth and both creativity and expected commercial success of new products. The relevance of breadth has been studied also to assess how key project attributes (complexity and uncertainty) are related to project openness. Bagherzadeh et al. (2021) show that in complex projects or when there are uncertainty about technologies and customer preferences, firms interact with a wide array of different partners. Hence, the first question this study will explore is: *Does 'Breadth' has an inverted U-shape relation with impactful projects?*

Recent studies on green innovation have investigated the external search strategy of green innovative firms in terms of 'breadth' (González-Moreno, Triguero, and Sáez-Martínez 2019; Kobarg et al. 2020; Liao and Tsai 2019; Li-Ying, Mothe, and Nguyen 2018; Martínez-Ros and Kunapatarawong 2019; Moreno-Mondéjar, Triguero, and Sáez-Martínez 2020; Muscio, Nardone, and Stasi 2017; Olsen, Sofka, and Grimpe 2017; Saez-Martinez, Avellaneda-Rivera, and Gonzalez-Moreno 2016; Triguero, Fernández, and Sáez-Martinez 2018). Empirical studies find confirmation of the positive effect of 'breadth' on green innovation (Martínez-Ros and Kunapatarawong 2019; Saez-Martinez, Avellaneda-Rivera, and Gonzalez-Moreno 2016; Triguero, Fernández, and Sáez-Martinez 2018), on firm growth (Moreno-Mondéjar, Triguero, and Sáez-Martínez 2020), and on the capacity to solve environmental problems by a group of actors (Olsen, Sofka, and Grimpe

2017). Although openness can benefit projects in many fields, environmental-related domains demand higher engagement of diverse stakeholders and different types of knowledge. Therefore, open projects that respond to environmental challenges are more likely to meet the object and have a higher impact on the actors involved. For green projects the relation between breadth of knowledge sources and impact is reinforced. Hence, the second question explored by this study is: *Do environmental purposes positively moderate the relation between 'breadth' and impactful projects?*

5 Dataset

The research questions discussed above are tested on a dataset of the research projects from the Seventh Framework Programme (FP7, hereafter), which was the main European research funding programme in the period 2007-2013. I select the specific programme on *Cooperation*. *FP7-Collaboration projects*[iii] have been previously used to investigate environmental sustainability and open innovation (Olsen, Sofka, and Grimpe 2017).

Usually, open innovation studies use innovation surveys (Ghisetti, Marzucchi, and Montresor 2015; Laursen and Salter 2006). These data are indicators of successful knowledge-searching strategy, which lead to the solution of specific problems. Instead, the advantage of using EU-funded projects is that they tackle a relevant problem which has not a solution yet. These projects signal the commitment of organizations that are willing to bear the cost of setting up a consortium, participating to a competitive call, and investing part of its own money in the funded project (Olsen, Sofka, and Grimpe 2017; Grimpe, Sofka, and Distel 2021). Since the proposal needs to be innovative and engage competent partners, these data present open innovation strategies in cutting-edge technologies with high strategic relevance.

6 Variables

6.1 Dependent variables

As measure of the impact of projects on the economy, *funds* refers to total funds received by the project. EU-funded programs aim at supporting excellence research, which can be achieved through the exchange of ideas and people mobility. Such high-level research is increasingly complex, interdisciplinary, costly and requires a critical mass (Defazio, Lockett, and Wright 2009). Larger grants imply higher complexity and costs (Tang, Fisher, and Qualls 2021), e.g. in terms of funding people mobility, hiring researchers, using state-of-the-art infrastructures, funding frequent and larger meetings to facilitate knowledge flows. Therefore, total funding is a proxy for the potential impact of the project on the scientific base of EU, on knowledge creation and diffusion, and – thanks to the involvement of firms – to innovation outputs.

We also employ another measure of the potential impact of projects, which is more strictly related to scientific outputs, i.e. publications (Lissoni et al. 2011). EU-funded grant holders of the FP7 programme are required to report, among other, scientific publications with every reporting period (usually, twice within the project duration) (Mugabushaka 2021). Publications linked to projects are provided by Cordis. In this study I used the last updated version in 7/09/2021. The variable *publications* measure the number of publications self-reported by the project participants. It is a measure of the quantity of knowledge produced as the result of the research collaboration of the funded project. As EU framework programmes aim at creating new excellent science that eventually impacts the industrial base, the number of publications capture how well the results of the projects advance the science. Publications are well-established outputs of EU-funded projects. Indeed, individual researchers have higher incentives to collaborate to publish and advance their career. However, firms may consider EU-funded collaborations more exploratory, suggesting that it is unlikely that EU-funded collaboration creates radically new scientific knowledge embodied in publications (Matt, Robin, and Wolff 2012).

6.2 Key independent variables

Following a well-established measure of openness, used also at the project level (Bagherzadeh, Markovic, and Bogers 2021; Grimpe, Sofka, and Distel 2021; Kobarg, Stumpf-Wollersheim, and Welpe 2019; Salge et al. 2013), the variable *breadth* counts how many different types of organizations are present in the project: Higher or Secondary Education Establishments (HES), Research Organisations (REC), Private for-profit entities (excluding Higher or Secondary Education Establishments) (PRC), Public bodies (excluding Research Organisations and Secondary or Higher Education Establishments) (PUB), and other (OTH).

Green is a binary variable equal to 1 if the project belongs to themes that are more strictly related to environmental challenges. Using the description of the themes (European Union 2013), it emerged that Energy and Environment are exclusively centred on environmental sustainability issues, but that also other themes have several references to sustainability, e.g. the electric vehicles, or more sustainable means of producing food (D'Agostino, 2020). Therefore, green projects are those belonging to the following *FP7-Cooperation* themes: Energy, Environment (included climate change), Transport, and Food, agriculture and biotechnology (KBBE). Themes such as Health, Information and Communication Technologies (ICT), and Space have no references to environmental sustainability, while some incidental green keywords are present in Nanosciences, Nanotechnologies, Materials and new Production Technologies (NMP), Socio-economic sciences and Humanities (SSH), and Security (for a detailed analysis of environmental-related contents of *FP7-Cooperation* themes see D'Agostino, 2020, ch. 3).

6.3 *Controls*

A set of controls is used in the regressions. A first group of variables is related to size. In the model with publications as dependent variable, *total cost* controls for the size of the project. *N. countries* controls for the number of different countries that participate in the project; greater number of countries may be related to higher complexity and the necessity to tap into multiple national systems of innovation. *Duration* measures the difference between the starting year and ending year; longer projects may be more complex.

A second set of controls is related to the reputation and experience of the coordinator. *Coordinator n. projects* measures in how many projects the organization is involved (this variable includes all FP7 calls, not only *FP7-Collaboration*). A more experienced coordinator enhances the probability of obtaining funds, but also ensures that the project is well-managed; this is especially important for large projects (Du 2021). Five dummies control for the type of activities of the coordinator (with universities as benchmark). We also control for the top-five nationalities of the coordinator. Germany, UK, France, Italy, and Spain are the countries with most organizations, both in the role of coordinator (60% of total coordinators) and participants (53%).

I also control for the role of more science-oriented organizations (Du, Leten, and Vanhaverbeke 2014). *Science Partners %* measures the number of universities and research organizations as share of total organizations. Since scientific organizations are more oriented to advance the scientific knowledge, they may pursue more ambitious and complex projects. Since projects may differ in the funds obtained, which may or not be close to actual cost of the project, I introduce a control for the funds received as share of total cost (*fund-cost ratio*).

Finally, I introduce fixed effects for starting years of the project (from 2008 to 2013), leaving other years as benchmark (i.e. 2007, and 2014-2015). Main statistics are reported in Table 1.

[tab. 1 here]

7 Methodology

I estimate potential impactful projects as function of openness, environmental-related content of the project, and a set of controls, through means of OLS, with clustered errors. To assess the inverse U-shape relation between breadth and project performance, I introduced the quadratic term $breadth^2$. To assess the moderating effect of *green*, I used the interaction between *breadth* and *green*.

The two dependent variables (*funds* and *publications*) are both taken in logarithm. All models are clustered by funding schemes[iv], which vary within each theme of *FP7-Cooperation*. Indeed, funding schemes are different in terms of the aim of the call (e.g. support of frontier research) and specific group addressed (e.g. SMEs). The *FP7-Cooperation* themes are related to 17 different funding schemes, and I aggregated 3 of them because of the low number of projects.

8 Descriptive analysis

As shown in Table 2, only 29.46% of the projects of the *FP7-Cooperation* calls fall into the green domain: energy (5.24%), environment (7%), food and agriculture (7.31%) and transport (9.91%). The themes that collect the largest number of projects are ICT (i.e. 2321) and health (i.e. 1008), while all the green themes have less than seven hundred projects each.

[tab. 2 here]

Table 3 provides the average values of key characteristics of the projects within each theme: funds received, total costs, fund-cost ratio, number of publications, and number of articles in peer-reviewed journals. Despite having fewer projects, FP7-ENERGY presents the highest average of both funds (4.8 million euro) and costs (8.3 million euro), follows by FP7-HEALTH. The aggregated means of green projects (bottom rows) are lower than non-green for both funds and costs. Hence, green projects are on average smaller than non-green projects. Health, nanotech, and security drive up non-green total funds and costs.

Table 3 also provides the ratio between funds and costs, as the project usually receives only a share of the total estimated cost. This ratio varies depending on the specific call and on the project. FP7-ENERGY presents a lower ratio (i.e. 0.67) than other themes. FP7-ENVIRONMENT and FP7-KBBE have above average ratios (i.e. 0.76), while FP7-TRANSPORT has one of the lowest values (0.72). Together, green calls have a lower fund-cost ratio than non-green projects.

Table 3 indicates the average number of publications by theme, including journal articles, books and book chapters, conference proceedings, and dissertations. Clearly, there are fields more productive than others, such as health with 24.2 publications per project, reflecting different practices across scientific disciplines. FP7-ENVIRONMENT and FP7-KBBE produce many publications (i.e. 16.73 and 15.37, respectively), while FP7-ENERGY and FP7-TRANSPORT very few (4.6 and 1, respectively). In aggregate, green projects exhibit lower publications on average (8.95 against 10.07 for non-green projects). Table 3 also provides the average number of articles that have been submitted to a peer-reviewed process that guarantees higher relevance of the new knowledge produced. In this case, ICT articles are significantly lower than overall publications, leading to green projects having a higher average of articles than non-green projects.

[tab. 3 here]

Table 4 presents an overview of the type of organizations involved in the project. The first five columns present the average number of organizations by project within each theme, the second block of columns presents the share of each organization type on total number of organizations, and the last column shows the variable *breadth*. We can observe that aggregated green projects have lower number of universities (3.83 vs 4); such differences seem to be driven by the non-green theme FP7-SSH and FP7-HEALTH. For all the other types of organizations, green projects have a higher number of partners. In terms of shares, universities are disproportionally present in many themes, mostly social sciences (60%), and health (47%). In aggregated, green projects present lower shares of universities than non-green projects. For all other types of organisations, instead, green projects present higher shares.

[tab. 4 here]

The last column in Table 4 shows the average values of the key independent variable *breadth*, which counts the number of different organizations participating in the project. The values range between 2.76 for FP7-SSH and 3.6 for FP7-ENVIRONMENT; indeed, green projects are on average more open than non-green projects (3.41 against 3.14).

9 Econometric analysis

The previous section has highlighted that green project are smaller and use wider sources of knowledge. In this Section, a multivariate analysis will provide more robust evidence of those insights. Table 5 provides the correlation table.

[tab. 5 here]

Table 6 shows the results of the OLS estimates where the dependent variable is *funds* in log. Model 1 presents the results of the relation between *breadth* and total fundings. The positive coefficients of *breadth* and the negative coefficient of its quadratic term (both statistically significant at $p<0.05$) point to an inverted U-shaped relation. A three-step procedure (Haans, Pieters, and He 2016; Lind and Mehlum 2010) reveals that the turning point of 4.12 lays quite close to the hedge of the curve. The overall test of the presence of an inverse U-shape is marginally significant, with a p-value equal to 0.05. The lower bound of the slope is statistically significant at $p<0.05$, therefore the increasing part of the curve is robust to testing. As shown in Fig. 1, the left-part of the curve (the decreasing part as suggested by the negative coefficient of the quadratic term *breadth*^{2}) is not confirmed by predictive margins. Hence, the relation between *breadth* and *funds* is very likely to be linear.

[tab. 6 here]

Model 2 presents the estimation with the inclusion of the variable *green*, and the interaction with *breadth*. Openness is positive and significant, as in model 1. *Green* is negatively associated to funds received ($p<0.05$), which means that environmental-related projects are on average smaller, as already observed in the descriptive analysis. However, the interaction term *breadth* × *green* is positive and statistically significant, which indicates how the relation between *breadth* and *funds* changes as we shift from non-green to green project; in particular, *green* makes this relation stronger. When *green* equals to 0, the effect on *ln funds* of one-unit increase in *breadth* is equal to the coefficient of *breadth* (i.e. 0.095), while when *green* equals as to 1, the effect of one-unit change in *breadth* on *ln funds* is the sum of the coefficients of *breadth* (i.e. 0.095) and *breadth* × *green* (i.e. 0.083), namely 0.178[v].

Fig. 2 graphs the predictive margins of *breadth* in green vs. non green project, which shows how *green* shifts the relation between *breadth* and *ln funds*, making the curve steeper. For green projects, each additional type of organizations involved in the project increases funds at a higher pace than for non-green projects. This result suggests the importance of wider sources of knowledge for environmental fields to purse greater and more complex projects.

As far as the controls are concerned, wider geographical scope (*n. countries*) is positively correlated to funds ($p<0.01$), probably a signal that larger grants require many actors located in many countries. *Duration* is positively and statistically significantly associated to greater funds ($p<0.01$). Longer projects may require several steps, hence they are more likely associated to larger projects. The coordinator plays an important role to obtain larger grants: *Coordinator n. projects* is positive and significant, albeit the effect is quite small. The share of funds as total cost of project is negatively associated to funds, which shows that for larger projects the share of cost sustained by organizations (i.e. the ones not funded by the grant) is relatively greater.

Table 7 shows the estimations where the number of publications is the dependent variable. In model 3, neither the *breadth* nor its quadratic term are statistically significant. In model 4, the interaction term *breadth* × *green* is not statistically significant, and neither *breadth* nor *green*. This result may be explained by the fact that scientific publications are mostly research output of universities, research centres and – to a less extend – firms; hence, they are less likely to be associated to projects with a wide range of actors.

[tab. 7 here]

As far as the controls are concerned, *duration* is positively and statistically significantly associated to publications. Hence, longer projects produce more scientific knowledge, perhaps because researchers have more time and materials to disseminate each phase of the project. Coherently with the scientific content of the project output, the share of scientific partners in the project is positive and statistically significant ($p<0.01$).

10 Discussion and conclusion

A complete understanding on how to design impactful research projects is lacking, despite the relevance for managers and policy makers (Du, Leten, and Vanhaverbeke 2014; Kobarg, Stumpf-Wollersheim, and Welpe 2019). As Europe is accelerating the transition to a more sustainable economy, the factors underlying successful green innovative projects need to be fully understood. In the context of EU-funded programmes, the main aim is to foster excellence research and disseminate knowledge, hence it is crucial to understand which characteristics of the project will be related to more ambitious, high-level projects. Building on a recent but fruitful stream of research on open innovation at the project-level and the importance of collaboration in environmental challenges, this paper addresses the issue of whether openness positively affects potential impactful project, and whether green domains positively moderate the relation between openness and impactful projects.

This paper provides evidence that the breadth of knowledge sources is positively related to larger projects, albeit not with an inverse U-shaped relation which is commonly found in GOI papers (e.g. Martínez-Ros and Kunapatarawong 2019). Breadth is not connected to a higher number of publications, a proxy for the quantity of knowledge created by the project. Research projects tackling environmental challenges in energy, natural environment, transportation and agriculture are smaller on average, but they render the effect of breadth on project performance stronger, signalling that for green projects each additional type of organizations involved increases the potential impact of the project. When considering scientific output (i.e. publications), neither the breadth nor the greenness of the projects are relevant.

I advance the a well-established stream of research on GOI about the role of the 'breadth' of knowledge sources by taking the point of view of the project (Bagherzadeh, Markovic, and Bogers 2021; Olsen, Sofka, and Grimpe 2017), rather than the more traditional firm-centric view.

Even though the European research program is a natural context where cooperation is encouraged and fostered, this paper highlights that - within the objectives common to all Cooperation themes (e.g. transnational cooperation, involvement of SMEs) - green topics attract a wider and more open consortia, and amplifies the importance of openness for impactful projects. This approach is backed up by the peculiarities of green innovation that require knowledge coming from different fields and industrial competences that may be transversal to many actors.

This paper suggests that managers willing to embark in green projects must consider a wider and diversified network of partners. This could be particularly important in European research programs, such as the new-born Horizon Europe.

These results must be taken with cautions. This first limitation of this study is that openness may be driven by the requirement of the specific call, rather than by the context of the project itself. I partially correct for this by using a broader definition of green, hence I include four themes (i.e. energy, environment, transportation and agriculture) in order to smooth the possible effect of the requirement for a single theme. In addition to that, by clustering by funding schemes I control for the variance coming from specific objectives (e.g. fundamental research or SMEs). The second limitation of this study is that important dimensions of the projects are lacking, such as the composition and ability of team member (Du 2021) or the strategic purpose of the organizations involved (Bagherzadeh, Markovic, and Bogers 2021). A third limitation is that only funded projects are included in the dataset; although this guarantees that only the most innovative and cutting-hedge projects are considered, it is unknown whether these results would be obtained for the other projects that still may have a certain level of relevance (indeed, many of the projects that fail to obtain a European grant are subsequently funded by national grants). Fourth, this paper uses a raw measure of greenness which derives from the cooperation themes; however, projects may vary in the relevance of the sustainability objectives, also within the same theme. For example, within the transport theme, we can have projects that reduce emissions of combustion engines as well as projects on electric engines for vehicles. The fifth limitation is that this paper provides evidence of correlation between key regressors and the dependent variables, not of causality.

Despite the above limitations, this paper contributes to advance the understanding of how openness and environmental sustainability are intertwined in research projects, and opens further research questions. Future research should combine firm-level characteristics and project-level characteristics in order to understand how company strategies moderate the relation between openness and project outcomes (Markovic et al. 2021); this requires to match Cordis data to business databases. Future research should also extend this approach to the latest framework programmes (i.e. Horizon 2020 and Horizon Europe), that increasingly place sustainability at the centre of the funding programmes. This is especially important since each framework programme has a specific design and distinctive objectives (Veugelers et al. 2015; Colombo, Pansera, and Owen 2019).

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Table 1- Summary statistics

Variable	Mean	Std. dev.	Min	Max
funds	3,703,019.00	3,411,856.00	15000	54,000,000
publications	9.74	28.03	0	1029
total cost	5,274,754.00	5,864,343.00	17,542.8	225,000,000
n. countries	6.79	3.26	1	37
duration	3.16	0.99	0	9
Breadth	3.22	0.93	1	5
Green	0.29	0.46	0	1
Coordinator n. projects	177.85	273.35	1	1652
Science Partners %	0.58	0.25	0	1
Fund-cost ratio	0.74	0.09	0.07	1
Country of the coordinator				
DE	0.17	0.37	0	1
UK	0.13	0.34	0	1
IT	0.11	0.32	0	1
ES	0.10	0.30	0	1
FR	0.10	0.30	0	1
Activity of the coordinator				
HES	0.39	0.49	0	1
PRC	0.23	0.42	0	1
PUB	0.02	0.15	0	1
REC	0.32	0.47	0	1
OTH	0.05	0.21	0	1

Table 2 – Number of projects by FP7-Cooperation themes

FP7 Cooperation	#	%
Green	*2079*	*29.46*
FP7-ENERGY	370	5.24
FP7-ENVIRONMENT	494	7
FP7-KBBE	516	7.31
FP7-TRANSPORT	699	9.91
Non-green	*4,976*	*71*
FP7-HEALTH	1,008	14.29
FP7-ICT	2,321	32.9
FP7-NMP	806	11.42
FP7-SECURITY	321	4.55
FP7-SPACE	267	3.78
FP7-SSH	253	3.59
Total	*7,055*	*100*

Table 3 – Average values of key indicators by themes

FP7-Cooperation themes	funds €	total cost €	funds ratio	publications	articles peer-reviewed
FP7-ENERGY	4,897,396	8,385,466	0.67	4.64	3.91
FP7-ENVIRONMENT	3,479,269	4,658,604	0.76	16.73	15.84
FP7-HEALTH	4,747,014	6,403,441	0.76	24.28	22.76
FP7-ICT	3,379,443	4,783,770	0.73	6.70	0.27
FP7-KBBE	3,586,831	4,845,287	0.76	15.37	14.54
FP7-NMP	4,017,840	5,779,345	0.72	8.07	7.58

FP7-SECURITY	4,168,541	5,870,881	0.74	1.78	1.54
FP7-SPACE	2,671,489	3,742,748	0.73	7.66	7.35
FP7-SSH	2,290,041	3,097,660	0.78	3.78	3.62
FP7-TRANSPORT	3,212,264	4,900,889	0.72	1.00	0.87
Total	3,703,019	5,274,754	0.74	9.74	7.15
Green	3,668,578	5,449,669	0.73	8.95	8.36
Non-green	3,717,409	5,201,673	0.74	10.07	6.64

Table 4 – Organization types

FP7-Cooperation themes	**#**					**%**					
	HES	PRC	PUB	REC	OTH	HES	PRC	PUB	REC	OTH	Breadth
FP7-ENERGY	2.72	4.44	0.58	2.73	0.52	0.24	0.41	0.05	0.25	0.05	3.22
FP7-ENVIRONMENT	5.02	2.91	1.12	4.75	0.91	0.33	0.21	0.07	0.32	0.07	3.60
FP7-HEALTH	5.47	2.30	0.59	2.74	0.44	0.47	0.22	0.04	0.23	0.04	3.21
FP7-ICT	3.71	3.96	0.34	2.03	0.44	0.38	0.35	0.03	0.20	0.05	3.07
FP7-KBBE	5.14	4.10	1.10	4.42	0.90	0.34	0.25	0.06	0.28	0.06	3.55
FP7-NMP	3.30	5.87	0.40	2.83	0.58	0.27	0.44	0.02	0.22	0.05	3.23
FP7-SECURITY	2.60	5.36	1.35	2.86	0.52	0.22	0.40	0.10	0.23	0.04	3.59
FP7-SPACE	2.40	3.05	0.68	3.35	0.49	0.25	0.33	0.06	0.31	0.05	3.09
FP7-SSH	6.57	0.54	0.69	2.66	0.67	0.61	0.05	0.05	0.24	0.05	2.76
FP7-TRANSPORT	2.62	6.13	0.57	2.48	0.71	0.22	0.47	0.04	0.21	0.06	3.28
Total	3.95	4.02	0.60	2.78	0.57	0.35	0.33	0.04	0.23	0.05	3.22
Green	3.83	4.56	0.83	3.55	0.77	0.28	0.34	0.05	0.26	0.06	3.41
Non-green	4.00	3.80	0.50	2.46	0.48	0.37	0.32	0.04	0.22	0.05	3.14

Table 5 – Correlation table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1 *ln* funds	1																			
2 *ln* publications	0.389***	1																		
3 *ln* total cost	0.988***	0.369***	1																	
4 n. countries	0.344***	0.185***	0.319***	1																
5 duration	0.600***	0.351***	0.588***	0.233***	1															
6 Breadth	0.286***	0.109***	0.268***	0.439***	0.156***	1														
7 Green	-0.051***	-0.050***	-0.038***	0.180***	0.034***	0.133***	1													
8 Coord. n. projects	0.076***	0.083***	0.071***	-0.014	0.084***	0.020*	-0.060***	1												
9 Sc. Partners %	-0.025**	0.280***	-0.064***	0.063***	0.120***	-0.165***	-0.091***	0.085***	1											
10 Fund-cost ratio	-0.305***	-0.029**	-0.445***	0.053***	-0.150***	0.006	-0.053***	-0.008	0.246***	1										
11 DE	0.042***	0.029**	0.043***	0.008	0.016	0.002	-0.009	0.180***	-0.021*	-0.024**	1									
12 UK	0.026**	0.023**	0.021*	0.006	0.064***	-0.023*	-0.006	0.020*	0.080***	0.026**	-0.172***	1								
13 IT	-0.001	0.013	0.001	-0.016	-0.047***	-0.005	-0.024**	-0.063***	0.002	-0.021*	-0.159***	-0.137***	1							
14 ES	-0.004	-0.043***	-0.001	-0.045***	-0.038***	0.015	-0.013	-0.079***	-0.080***	-0.023*	-0.151***	-0.130***	-0.120***	1						
15 FR	-0.005	-0.034***	0.006	0.026**	-0.005	0.063***	0.016	0.091***	-0.058***	-0.066***	-0.151***	-0.130***	-0.120***	-0.114***	1					
16 Coordinator HES	0.045***	0.206***	0.021*	-0.026**	0.129***	-0.127***	-0.125***	0.030**	0.363***	0.132***	-0.035***	0.235***	-0.01	-0.117***	-0.203***	1				
17 Coordinator PRC	-0.002	-0.189***	0.025**	-0.050***	-0.132***	-0.012	0.025**	-0.299***	-0.406***	-0.179***	-0.01	-0.024**	0.029**	0.063***	0.101***	-0.430***	1			
18 Coordinator PUB	-0.047***	-0.028**	-0.035***	0.053***	0.008	0.049***	0.056***	-0.082***	-0.118***	-0.018	-0.049***	0.031**	-0.013	0.01	-0.002	-0.123***	-0.083***	1		
19 Coordinator REC	0.004	-0.002	0.001	0.047***	0.002	0.079***	0.065***	0.236***	0.080***	0.008	0.081***	-0.212***	0.01	0.080***	0.048***	-0.543***	-0.368***	-0.105***	1	
20 Coordinator OTH	-0.077***	-0.077***	-0.078***	0.018	-0.049***	0.108***	0.056***	0.062***	-0.130***	0.044***	-0.043***	-0.052***	-0.048***	-0.038***	0.166***	-0.174***	-0.118***	-0.034***	-0.149***	1

Table 6: Econometric analysis: log of total funds (*ln funds*)

	(1) *ln funds*	(2) *ln funds*
Breadth	0.509***	0.095***
	(0.135)	(0.019)
$Breadth^2$	-0.062***	
	(0.019)	
Green		-0.495**
		(0.172)
Breadth × Green		0.083**
		(0.034)
n. countries	0.051**	0.054**
	(0.019)	(0.019)
duration	0.413***	0.419***
	(0.071)	(0.072)
Coordinator n. projects	0.000***	0.000***
	(0.000)	(0.000)
Science Partners %	-0.073	-0.108
	(0.070)	(0.086)
Fund-cost ratio	-2.129***	-2.231***
	(0.439)	(0.443)
Constant	14.135***	14.860***
	(0.518)	(0.360)
Observations	7,055	7,055
R-squared	0.509	0.516
T-test for Inverted U-shape	0.05	
Wald test for interaction		0.00

*** p<0.01, ** p<0.05, * p<0.1
Standard errors in parentheses, clustered by 14 funding schemes.
All models include dummies for home country of coordinator: DE, FR, UK, IT and ES; dummies for type of activity of the coordinator; dummies for starting year (2013 - 2018)

Table 7: Econometric analysis: log of publications (*ln publications*)

	(3) ln pubs	(4) ln pubs
Breadth	0.063	0.064
	(0.194)	(0.044)
Breadth 2	0.001	
	(0.029)	
Green		-0.135
		(0.186)
Breadth × Green		0.023
		(0.074)
ln total cost	0.542***	0.534***
	(0.070)	(0.066)
n. countries	0.006	0.007
	(0.018)	(0.016)
duration	0.156**	0.159**
	(0.054)	(0.055)
Coordinator n. projects	0.000	0.000
	(0.000)	(0.000)
Science Partners %	1.293***	1.282***

	(0.227)	(0.223)
Fund-cost ratio	1.094*	1.045*
	(0.516)	(0.501)
Constant	-9.427***	-9.265***
	(1.567)	(1.491)
Observations	7,055	7,055
R-squared	0.268	0.268

*** p<0.01, ** p<0.05, * p<0.1
Standard errors in parentheses, clustered by 14 funding schemes.
All models include dummies for home country of coordinator: DE, FR, UK, IT and ES; dummies for type of activity of the coordinator; dummies for starting year (2013 - 2018)

Fig. 1 – Predictive margins: breadth

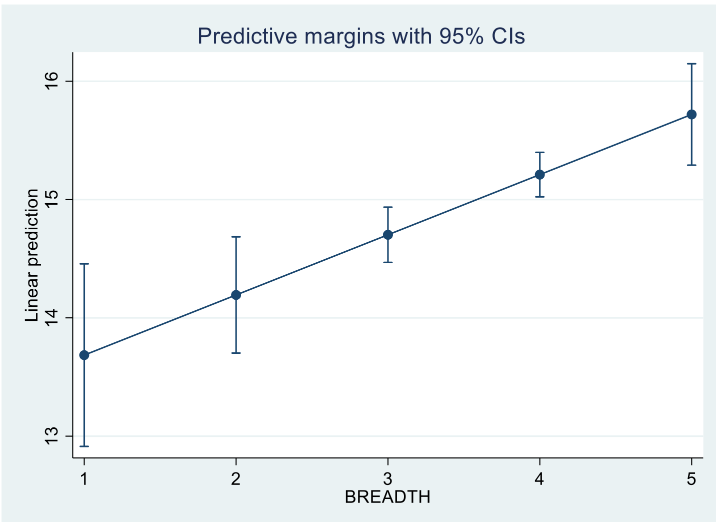
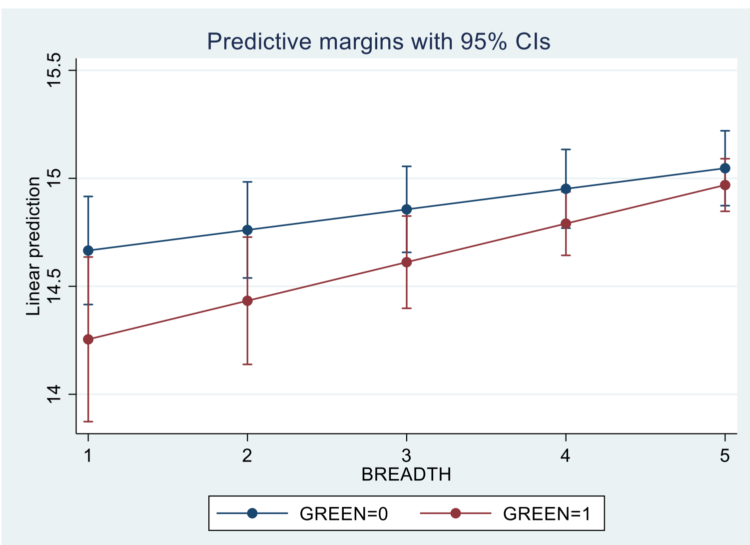


Fig. 2 – Predictive margins: breadth for green vs non-green projects



[i] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en#documents

[ii] See the complete list of partners at https://www.paboco.com/community (last access January 2022)

[iii] Open data are drawn from https://cordis.europa.eu/en (last access December 2021)

[iv] See https://cordis.europa.eu/programme/id/FP7 for further information on the types of funding schemes of the FP7.

[v] The Wald test of the null hypothesis that all the coefficients associated with the interaction are different than 0 reports a significant p-value ($p<0.00$), hence the coefficients are non-zero.