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Environmental innovation and cooperation: A configurational approach

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ABSTRACT

Firms are increasingly pressured to introduce green innovations. The literature suggests that – given their high complexity – collaborating with external stakeholders is a key ingredient in the effective development of green innovations (GI), even more so than for 'traditional' types of innovation. While there is evidence that firms engage with more than one partner at once and that not all those collaborations result in higher innovation performance, nothing is known regarding the combination of collaborations that provides the highest GI performance. To address this gap, this paper uses a qualitative comparative approach (QCA) to identify these potential conjoint effects on GI propensity. By means of a csQCA analysis of Spanish firms, we find seven equifinal paths leading to high innovative performance—cooperating with universities but not with private consultants; cooperating with universities and with suppliers; and cooperating with suppliers and customers being by far the most diffused.

1. Introduction

In recent years, terms such as 'global warming', 'greenhouse gasses' or 'carbon footprint' have become common in economic and social fields and policy agendas. Companies are called to play a critical role in responding to these major global challenges by developing new products or production processes that reduce environmental impacts, e.g. introducing green innovation (GI). However, this is not an easy task given the high level of complexity that characterises these types of innovations (Cainelli et al., 2015; De Marchi, 2012; Pinkse and Kolk, 2010). Accordingly, identifying strategies to improve firms' ability to introduce GI is a key goal for both policymakers and managers.

Firms activate several resources to effectively introduce new products or processes to the market that can reduce environmental impacts (Awan et al., 2021). Studies on GI suggest that implementing an open approach to innovation, i.e. collaborating with external stakeholders on innovation, is key to effectively introduce GI, even more crucial than to develop other types of innovations (Cainelli et al., 2015; De Marchi, 2012; Niesten et al., 2017; Awan and Sroufe, 2020; Sánchez-Sellero and Bataineh, 2021). Indeed, collaborating with suppliers, customers, universities or knowledge-intensive business services (KIBS) might provide firms the opportunity to access complementary resources and capabilities, reduce risks or costs and enhance their competitive advantage (Niesten and Jolink, 2020).

If there is extensive literature on the importance of collaborating (with any partners), little is known about whether and how collaborations with different partners can be combined to ensure higher innovation performance. Most studies so far, indeed, have taken a linear approach in the analysis of collaborations, verifying the net effect of single explanatory factors, i.e. collaboration with suppliers, customers, universities or KIBS or collaboration with any of them (see e.g., De Marchi, 2012; De Marchi and Grandinetti, 2013; del Río et al., 2015). However, studies suggest that collaborating with more partners at once is beneficial for environmental innovativeness (Marzucchi and Montresor, 2017; Rauter et al., 2019), but only up to a point (Ghisetti et al., 2015). Further empirical evidence reports that each of these types of actors entails different capabilities and contributes differently to the eco-innovative effort (Bigliardi et al., 2012; Melander, 2018; Niesten and Jolink, 2020; Watson et al., 2018). Thus, as managers face the practical problem of how to best organise to develop GI, they should not only consider which type of actor to engage with, but also what different types of collaborations can be jointly activated to increase their chances of overcoming innovation challenges and effectively introducing GIs to the market. Accordingly, in this study, we ask the following question: ***What combination of partners do firms need to collaborate on innovation with, to effectively introduce GI?***

To address this question, we conceptualise collaboration on innovation as a configurational phenomenon in line with Martínez-Cháfer

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et al. (2021). Configurational theories and methods allow us to conceive and measure causally complex phenomena, considering that multiple explanatory factors jointly lead to an outcome (*conjunction)* and that the same outcome might be achieved by different paths (*equifinality)* (Furnari et al., 2021; Misangyi et al., 2017). Accordingly, we research the configurations of collaborations with external partners that drive the propensity to introduce new green products or processes. By means of a qualitative comparative analysis (QCA) based on innovation survey data (CIS) on Spanish firms, we identify seven equifinal paths that drive higher GI propensity, suggesting different avenues that firms might implement to access the complementary knowledge and capabilities needed to develop innovations addressing climate challenges.

Our study contributes to the extant literature by advancing theory, research methods and practice. Theoretically, we contribute to the literature on GI, and in particular on collaborations for GI, by proving the importance of jointly considering cooperation on innovation with different actors to understand firms' propensity to introduce GIs. We also suggest the existence of multiple paths for companies to achieve the same results – introducing environmental innovations, moving away from the linear approach latent in most of the literature on the topic (e.g., De Marchi and Grandinetti, 2013; Ghisetti et al., 2015; Marzucchi and Montresor, 2017). A variety of ways that collaboration with external partners can support GI propensity is outlined, also accounting for potential trade-offs among cooperative agreements. Such results entail actionable knowledge for managers too, providing different 'recipes' through which they can substantiate their open innovation strategies to increase their likelihood of effectively introducing GI. Methodologically, our study is the first to analyse, with a configurational approach, the engagement in collaboration on innovation in the context of GI. Similarly to Juntunen et al. (2019), we address the questions of how broad and deep the net of external collaborators for GI should be. Departing from their approach, however, we unpack the variety of configurations integrating different types of partners—including both supply chain partners (customers and suppliers), knowledge organisations (KIBS, research centres, universities) and competitors. So far, such a configurational approach has been used only in the analysis of general innovation (Martínez-Cháfer et al., 2021); this, however, entails some significant differences with GI as far as cooperation is concerned (Cainelli et al., 2015; De Marchi, 2012).

This paper is structured as follows. First, we discuss the theoretical basis of the research, and then we move to the description of the empirical setting and describe the results. Finally, the findings and conclusions are proposed.

2. Environmental innovations

2.1. Definition and peculiarities

By spurring new products, processes or non-technological changes that are respectful of the environment (i.e., allowing energy or material saving, pollution prevention, waste reduction, protection of biodiversity), environmental innovation might allow firms to implement production models with lower impacts while ensuring building a competitive advantage. Green, environmental or eco-innovations (Díaz-García et al., 2015; Franceschini et al., 2016) can be defined as changes in the product, production process, service or managerial method that prevent or reduce environmental damage, pollution and other negative impacts of the use of resources, as compared with relevant alternatives (Kemp and Pearson, 2007). Considering their potential to reduce the burden of economic activities on the environment, several actors are pressuring firms to change their production processes and product offers to account for environmental impacts—including consumers or global buyers (De Marchi et al., 2013; Yang and Rivers, 2009), non-governmental organisations (NGOs) and civic societal organisations (de Bakker et al., 2019; Nadvi, 2008), and governmental agencies and policymakers (Berrone et al., 2013; Jaffe et al., 2005). GIs are increasingly becoming strategic for companies too, either because of corporate responsibility attitudes or because of strategic intents (Bansal and Roth, 2000; Orsato, 2006).

While firms are increasingly challenged and motivated to introduce green innovations, the question remains of how to do so effectively. Indeed, innovating for environmental sustainability presents companies with complex challenges (Cainelli et al., 2015; Carrillo-Hermosilla et al., 2010; Pinkse and Kolk, 2010). It requires firms to adopt a systemic approach to design and production and deeply integrate with supply chain partners; move away from existing technologies and master new, often unrelated capabilities; address market and technological uncertainties; and navigate trade-offs between economic and environmental elements (Cainelli et al., 2015; Carmine and de Marchi, 2022; Pinkse and Kolk, 2010). A diffused approach to deal with such complexities is to develop inter-firm alliances aimed at generating innovation and knowledge development. Engaging with external stakeholders, indeed, allows firms to share complementary knowledge, improve risk management and develop the ability to effectively respond to stakeholder pressures, achieving important environmental performances (Niesten and Jolink, 2020; Watson et al., 2018). Several empirical contributions suggest that cooperation with external actors is a key element of GI development, being even more relevant than other types of innovations, representing one of its most crucial peculiarity (De Marchi, 2012; del Río et al., 2016; del Río et al., 2011; Zhu et al., 2021).

2.2. Cooperating on GI

Firms might engage with various types of collaborators. These partners entail diverse capabilities and contribute in a different role to their eco-innovative efforts (Bigliardi et al., 2012; Melander, 2018; Niesten and Jolink, 2020; Watson et al., 2018; Awan and Sroufe, 2020; Sánchez-Sellero and Bataineh, 2021). Studies spanning the green or sustainable supply chain literature support the importance of engaging in closer coordination with suppliers and clients to develop new products and processes that can close the loops and reduce emissions (e.g. Seuring and Müller, 2008). Collaborations with suppliers have been found to be particularly effective in addressing incremental, process-related environmental innovations or circular economy product innovations (Kobarg et al., 2020). Cooperation with clients and users might be very effective in closing the loops and identifying eco-design issues—for example, allowing the collection of materials to be used as secondary materials; or enhancing the acceptance of the solutions developed (e.g. Heiskanen and Lovio, 2010; Slotegraaf, 2012). Cooperation with public or private technical or knowledge partners, such as universities or KIBS, might be particularly helpful for developing new standards and knowledge spanning firms' traditional boundaries and effectively leveraging the market for advanced innovation processes (Di Maria et al., 2019; Triguero et al., 2013).

Very often, firms engage with different types of partners at once, depending on the specific knowledge and technological needs related to the eco-innovation to be introduced. Actually, in line with the general literature on innovation (see Laursen and Salter, 2006), empirical evidence suggests that the more the typologies of partners the firms engage in innovation with, the higher the environmental innovative performances of firms (De Marchi and Grandinetti, 2013; Marzucchi and Montresor, 2017; Rauter et al., 2019), yet only up to a point (Ghisetti et al., 2015). The relationship between openness and innovation performance is indeed curvilinear, as cooperating with innovation is not costless. Engaging with several and diverse partners for innovation purposes requires important organizational and managerial energies, including the need for developing a shared understanding and common routines and processes (Ghisetti et al., 2015; Laursen and Salter, 2006). Accordingly, it is important to develop selective cooperative strategies (Juntunen et al., 2019), identifying with great care which combinations of cooperative agreements to *jointly* activate. Accordingly, a key question emerges: what patterns of cooperating partners are best able to provide firms with the needed skills and resources to introduce to the market innovative products or processes that tackle environmental issues?

The current empirical research on collaboration for GI leaves this key question open, as it has either focused on i) collaboration without considering the specific partners engaged or their number (e.g. De Marchi, 2012); ii) the optimal number of partners the networks should be formed out of, irrespectively to the type of partner (e.g. Ghisetti et al., 2015); iii) or the effects of each cooperating partner in isolation (e.g., De Marchi and Grandinetti, 2013). Such approaches might lead to overlook the possible interactions among cooperation agreements with different partners, which are particularly relevant considering that they entail complementary capabilities (Niesten and Jolink, 2020). In addition, they could lead firms to waste resources in activating unnecessary collaborations or to miss market opportunities, if not activating all the necessary needed ones. Accordingly, our analysis focuses on identifying potential configurations of cooperation activities that allow the introduction of GI, unravelling different 'recipes for success'.

3. Empirical setting

3.1. Data

In this research, we have based our analysis on data from the Spanish Technological Innovation Panel (PITEC). This panel-type database enables the analysis of the technological innovation activities of Spanish companies, including information on environmental innovation. The survey is carried out annually due to a joint effort by the National Statistics Institute (INE) and the Spanish Foundation for Science and Technology. These two entities also receive advice from academic experts when they implement the different survey waves, which date back to 2003. In this study, we focused on the 2015 wave, the last for which data on green innovation is available.

Using PITEC is appropriate for several reasons. One of the most important ones relies on the fact that the survey implements in the Spanish context the Community Innovation Survey (CIS), one of the most diffused datasets in innovation studies, and enables comparison with other data sources or contexts, as it is performed in most European countries since 2003. Additionally, it includes information that allows to clearly capture environmental innovations, as a specific, one-off module has been added to understand this phenomenon. The 2015 wave includes that information, having 12,844 observations. Due to the characteristics of the analysis performed in this research effort, we finally restricted our attention to 4685 cases that, complying with the QCA requirement, are complete.

3.2. Method

Traditional empirical analyses aimed at testing hypotheses are normally based on probabilistic statistical tools, such as many types of regressions, or other modelling approaches, like structural equations. However, these approaches fail to explain the corresponding theoretical backgrounds, as they normally provide results that concentrate on the net effects of the variables (Eggers et al., 2020). Because of this, it is quite common that we find conflicting results in the literature that derive from the narrow and individual perspective that stems from these traditional methodologies. Alternatively, some different approaches have rapidly gained attention recently. This is the case with the QCA, which has been applied to many different fields, such as industrial clusters, innovation and economic geography or institutional collaboration, among others (Martínez-Cháfer et al., 2021; Garcia-Alvarez-Coque et al., 2020; Berné-Martínez et al., 2021).

Thus, in this paper, we use QCA to disentangle the complex causality behind the cooperation activities that yield to the development of environmental innovations in firms. Complex causality implies the influence of diverse characteristics on the phenomena under study. According to Meyer et al. (1993), these characteristics include the existence of conjunction (the interaction among diverse forces), equifinality (different combinations of elements that yield the same result) and asymmetry (interactions among the elements and the results may not always be the same depending on the case). Stemming from the work of Ragin (2008, 2009), QCA has three main variants: csQCA, mvQCA and fsQCA. Among these, csQCA is the approach that bases itself on the use of dichotomous empirical data that correspond to our empirical setting for this research effort (Guerola-Navarro et al., 2021). csQCA is based on set theory and Boolean logic, which enable the analysis of multiple conjoint causality.

According to Ragin (2009), the underlying idea of the QCA methodology is identifying the necessary and/or sufficient conditions that enable a particular outcome to occur. In this sense, a condition is understood to be sufficient when its presence is enough to cause the corresponding outcome. In cases where a combination of conditions explains the existence of the outcome, multicausality emerges. Translated into set theory, this would imply that the set of cases with the condition(s) is a subset of those with the outcome. Conversely, a necessary condition is present whenever the outcome occurs, which, in set theory, would imply that the set of cases with the outcome is a subset of the set with the condition(s) (Cooper and Glaesser, 2016) (see Fig. 1).

To carry out our csQCA analysis, we followed the common steps that can be found in the specific literature (Guerola-Navarro et al., 2021; Ragin, 2008; Ragin, 2009; Thiem and Dusa, 2013). The process starts by identifying the set of relevant cases in which csQCA does not allow the existence of missing variables. In our case, from the original database, we accounted for 4685 complete cases for the variables that we used. We proposed a model that contains an OUTCOME (in our case, green innovation) and CONDITIONS that are related to various types of business cooperation.

Green Innovation = *F* (*Cooperation with Suppliers, Cooperation with Customers, Cooperation with Competitors, Cooperation with Consulting, Cooperation with Universities and Research Centres*)

The components of the model that we used in our configurational approach can be found, along with a short description, in Table 1.

Once the cases are identified and the model with the corresponding variables is in place, the next step is to generate the truth table. This table lists all the logical possible combinations of the corresponding conditions. Accordingly, the number of rows of the truth table is 2^k, where k is the number of conditions applied in the model. The table also includes what the csQCA identifies as logical reminders or logical possible combinations that do not appear in our list of cases (Ragin, 2009; Guerola-Navarro et al., 2021). After reducing the truth table with the use of the Dusa (2019) R Package, we obtain the corresponding solutions.

In sum, csQCA tries to explain the causal complexity of the phenomena studied through two types of analysis: necessity and sufficiency analysis (Ragin, 2008). These two analyses are carried out sequentially. First, by means of the necessity analysis, we will try to determine whether the presence or absence of any of the conditions studied is necessary to belong to the set called OUTCOME (in our case, green innovation). Once the necessary presence or absence is determined, we proceed to perform the sufficiency analysis to detect those conditions, or combinations of them, that are sufficient to yield the OUTCOME.

4. Results

In this section, after describing the main steps of the csQCA process in the empirical setting, we outline the main results of the different parts of the analysis.

4.1. Necessity analysis

In Table 2, we can see the results of the analysis of necessity that contemplates the presence of the OUTCOME. These results indicate that

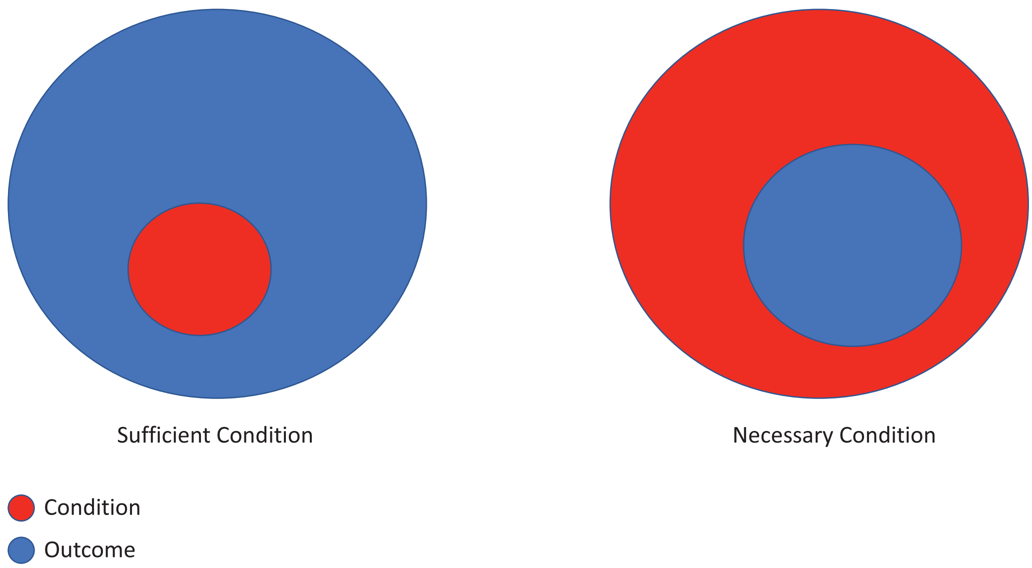

Fig. 1. Necessary vs. sufficient conditions.

Table 1
Definition of the outcome and the conditions together with references to articles illustrating the relationship between them.

Type	Name and code	Description	Relation outcome/ condition
Outcome	Green innovation	Objectives of companies related with the development of green innovations.	(De Marchi, 2012*)
Condition	Cooperation with suppliers	Existence of cooperative activities on innovation with this type of actor.	(Andersen, 1999*; De Marchi, 2012*; Geffen and Rothenberg, 2000*; Meyer et al., 2000; Theyel, 2006*; Awan and Sroufe, 2020)
	Cooperation with customers	Existence of cooperative activities on innovation with this type of actor.	
	Cooperation with competitors	Existence of cooperative activities on innovation with this type of actor.	(Boari et al., 2017; Boari et al., 2003; De Marchi, 2012*; Tomlinson, 2010)
	Cooperation with KIBS	Existence of cooperative activities on innovation with this type of actor.	(Bergquist and Söderholm, 2011; De Marchi, 2012*)
	Cooperation with Universities and Research centres (RC)	Existence of cooperative activities with this type of actor.	(Bossink, 2007; De Marchi, 2012*; Molina-Morales and Martínez-Cháfer, 2016; Norberg-Bohm, 2000)

Note: The references outlined in this table correspond to studies about both innovations in general and GI (signalled with an *). The specific survey items used to calculate the variables are described in the appendix.

no condition, both in its presence and absence (noted as ~), obtains adequate values to be considered necessary. The consistency value for a condition to be considered necessary must be greater than 0.9 (Schneider et al., 2010), and none of the consistency results reported in Table 2 exceeds that value. We can interpret the results in the following way: No single collaborating partner is necessary to be able to introduce green innovations. In other words, it is possible to be green innovators whether collaborating or not with any of the partners considered in the survey; there is no necessary 'one best way' that emerges.

We also conducted a necessity analysis regarding the absence of the OUTCOME, as can be seen in Table 3. In this case, there were some conditions that presented values of consistency above 0.9. This is the case in the absence of relationships with customers, competitors and consulting entities. However, these cases turn out to be trivial due to the fact that their relevance of necessity (RoN) scores are always below 0.6 (Schneider and Wagemann, 2012). As for the above, those results can be interpreted in the following way: not introducing green innovation is not necessarily linked with collaboration with a specific actor. To say it differently, firms failing to introduce GI do not all have in common

Table 2
Necessity analysis OUTCOME (Introducing GI).

	Consistency	Relevance of necessity	Coverage
Cooperation with suppliers	0.269	0.956	0.833
Cooperation with customers	0.214	0.973	0.861
Cooperation with competitors	0.130	0.980	0.830
Cooperation with KIBS	0.160	0.979	0.854
Cooperation with Universities and RC	0.360	0.937	0.835
~ Cooperation with suppliers	0.731	0.429	0.630
~ Cooperation with customers	0.786	0.356	0.637
~ Cooperation with competitors	0.870	0.255	0.656
~ Cooperation with KIBS	0.840	0.291	0.648
~ Cooperation with Universities and RC	0.640	0.511	0.608

Note: ~ stands for condition's absence.

Table 3
Necessity analysis for the absence of the OUTCOME (not introducing GI).

	Consistency	Relevance of necessity	Coverage
Cooperation with suppliers	0.111	0.812	0.167
Cooperation with customers	0.071	0.852	0.139
Cooperation with competitors	0.055	0.911	0.170
Cooperation with KIBS	0.056	0.890	0.146
Cooperation with Universities and RC	0.147	0.745	0.165
~ Cooperation with suppliers	0.889	0.306	0.370
~ Cooperation with customers	0.929	0.240	0.363
~ Cooperation with competitors	0.945	0.152	0.344
~ Cooperation with KIBS	0.944	0.182	0.352
~ Cooperation with Universities and RC	0.853	0.403	0.392

Note: ~ stands for condition's absence.

collaboration with one partner. Accordingly, in the following, we perform a sufficiency analysis to identify alternative, sufficient paths.

4.2. Sufficiency analysis

To perform the sufficiency analysis, we start by calculating the truth table that includes all the possible logical combinations according to the methodological recommendations of Fiss (2011) and Ragin (2008). The truth table acts as the first synthesis of the raw data table. In the model we have proposed for this research effort, there are 32 possible configurations of conditions (2^5) corresponding to the five different types of cooperation that we have considered. From all these 32 possible configurations, our truth table shows one logical remainder (the non-observed configuration). This means that we have appropriate diversity in our data, so the results discussed in the following are meaningful.

In Table 4, we can find the results for the sufficiency analysis, reporting all the combinations that lead to the same outcome: being able to introduce innovations and reducing the environmental footprint. To perform this analysis, we selected a consistency threshold of 0.75, best aligned with large-N studies, and a frequency cutoff of two. To display the sufficiency analysis results, we followed the recommendations of Fiss (2011) and Ragin (2008), showing the presence of a condition with black squares and its absence with empty circles. Blank spaces mean that the particular condition does not matter, i.e. that it is not relevant in determining the outcome. The overall consistency is 0.840 and the solution coverage is 0.388, which is above the threshold suggested in the literature to ensure meaningful results (see Fiss, 2011; Ragin, 2008).

As reported in Table 4, our analysis suggests there are seven different potential 'recipes' for being a green innovator, each with a different relative importance. Indeed, the first three configurations show values of coverage significantly higher than the rest of the options, meaning that those causal configurations are more recurrent in the sample considered. In particular, Path 1 ("Science driven") is the most diffused (having greater raw (0.230) and unique (0.098) coverage values), followed by Paths 2 ("Upstream research") and 3 ("Supply chain integration"), which also have notably superior values of coverage in comparison with the subsequent paths obtained.[1]

In the following, we describe in detail the three most diffused paths, relating emerging evidence with the extant literature (both on GI and on general innovation) - see Table 5 for a summary. Path 1 (which we named "Science-driven"), reports that, to be innovatively green, firms should cooperate with universities and public research centres (RC), but not with private KIBS. We might interpret this result in light of the substitutive role of these two partners, which was already suggested in a similar empirical setting for general innovation by Pinto et al. (2015) and Martínez-Cháfer et al. (2021). Both KIBS and universities provide knowledge that contributes crucially to firms' high innovative capacity. While KIBS are perceived to be more accessible, universities might be most complex to interact with—there is a need for the greatest internal human and innovation resources to interact effectively with universities, especially when it comes to formal interaction, which is analysed in this paper (Apa et al., 2021; Kobarg et al., 2018). For firms with important internal capabilities, however, universities might provide more advanced knowledge than KIBS. While universities, via their basic and applied research efforts, are focused on developing advanced solutions, KIBS are likelier to transfer and recombine existing knowledge or co-develop more incremental types of innovations. Accordingly, we might interpret Path 1 ("Science-driven") with the importance of focusing the cooperation effort with just one of those knowledge-intensive providers—the one that might allow for the achievement of a higher level of innovativeness, i.e. the universities. Further research should better investigate this issue, on which there is very little knowledge in the more general innovation literature, even when accounting for different characteristics of the firms, as in Tether and Tajar (2008).

Path 2 ("Upstream research") also accounts for a great deal of diffusion among the cases under analysis. The basis of this 'recipe' for GI relies on the conjoint presence of cooperation with universities and research centres and with suppliers. Individually, both ingredients have been widely discussed in the GI literature (Cainelli et al., 2012; Cuerva et al., 2014; De Marchi, 2012). We might interpret the result as the interaction of two complementary sources of valuable knowledge: the advanced knowledge of research frontiers provided by universities, and the applied knowledge of the production process or of its inputs provided by suppliers. Collaborating jointly with both types of partners might ensure the development of breakthrough ideas that can be effectively implemented with firms' production processes and operations. In the general innovation literature, this conjoint collaboration has been identified, for example, in the cluster literature focused on traditional sectors, such as the ceramic industry (Molina-Morales and Martínez-Cháfer, 2016). Interestingly enough, this combination is often indirectly acknowledged in the policy realm: for example, many of the EU projects under the LIFE Programme—the programme for the environment and climate action— strongly recommend the inclusion of both universities and suppliers in the consortium to be funded[2].

Path 3 ("Supply Chain Integration") involves vertical relationships of companies along the supply chain. In line with the literature supporting the importance of supply chain integration in achieving superior environmental sustainability results (Kang et al., 2018; Wiengarten and Longoni, 2015), our results suggest that to become highly innovative in green issues, it is important to engage with both suppliers and customers. An abundant literature has investigated the role of suppliers and customers *separately* in supporting the development of GI (see Table 5); our results indeed suggest that it is their conjoint effect that leads to superior GI performance. Those results can be interpreted in line with the importance for firms to close the loops; developing products and processes that enable end-of-life product recovery, refurbishing or remanufacturing, the use of recyclable and recycled materials and the reduction wastes along the entire supply chain (Bakker et al., 2014; Hofstetter et al., 2021). Firms interested in innovating to achieve the circular economy, indeed, might need to engage both with customers – to collect end-of-life products or to improve the usage of products, and with suppliers – which use the collected waste to create recyclable inputs. Descriptions of innovation for the circular economy in industries as different as the fashion (Franco, 2017) and the plastic industries (Gong et al., 2020) provide interesting examples of the importance for firms to engage both partners to effectively close the loops[3].

5. Discussion

In sum, we obtain a portfolio of equifinal paths that supports the idea of a conjoint effect of different typologies of collaborations towards the development of green innovations. Our empirical results confirm that analysing one type of partner at a time might be misleading in the interest to identify what is needed for firms to become a green innovator, yet there is not a one-way that fits-all; rather 7 different paths emerge.

However, some categories of external partners are more relevant than others. Universities and research centres are the most popular cooperation partners in the results obtained—they are present in four out of seven causal configurations, including the two most diffused

[1] While those three paths are the most diffused, please note that the others are likewise able to achieve the outcome, i.e. to introduce GI.

[2] See, for example, the LIFE programme: https://cinea.ec.europa.eu/life_en.

[3] Given their numerical relevance in the sample, we focused here just on the three most diffused paths. A description of the other four paths (4 - "Downstream research"; 5 – "Demand driven"; 6 – "Systemic effort"; 7 – "Industry wise") is offered in Table 5.

Table 4
Sufficiency analysis.

Configuration no.	Paths						
	1 (Science driven)	2 (Upstream research)	3 (Supply chain integration)	4 (Downstream research)	5 (Demand driven)	6 (Systemic effort)	7 (Industry wise)
Cooperation with suppliers		■	■			■	
Cooperation with customers			■	■	■		○
Cooperation with competitors				○	○	■	■
Cooperation with KIBS	○				○	■	
Cooperation with universities and RC	■	■		■			■
Raw coverage	0.230	0.192	0.145	0.093	0.092	0.061	0.033
Unique coverage	0.098	0.021	0.008	0.006	0.018	0.001	0.003
Consistency	0.798	0.903	0.907	0.868	0.822	0.941	0.811
Solution coverage	0.388						
Solution consistency	0.840						

Note. As per Fiss (2011), black squares correspond to the presence of antecedent conditions. White circles indicate the absence or negation of antecedent conditions. The blank cells represent ambiguous conditions. Frequency cut-off: 2; Consistency cut-off: 0.75; Directional expectations: (-,-,-,-,-,). csQCA in Low-N samples often strives for perfect consistency with a cut-off of 1. However, the consistency cut-off choice in this paper is aligned with the number of cases. Indeed, large-N QCA studies inevitably encounter more contradicting configurations than much smaller samples (Ragin, 2000, 2006). See the appendix for a separated analysis and interpretation of the cases that cause the contradictions according to the recommendations of Rihoux and De Meur (2009).

configurations. These results are in line with previous studies highlighting their importance, as they provide complementary expertise in the development of novel and advanced GI (De Marchi and Grandinetti, 2013; Di Maria et al., 2019; Triguero et al., 2013). The general literature on innovation, suggesting the role of universities in cases where firms are interested in developing complex and radical innovations (Bossink, 2007; Molina-Morales and Martínez-Cháfer, 2016; Norberg-Bohm, 2000), further confirms those results, given the peculiarities of GI discussed in the literature review. Along the same lines, suppliers and customers also seem to be quite relevant as a cooperation option with three participants each, following the literature supporting the importance of strong supply chain integration for fully addressing sustainability issues, especially when firms are interested in closing the loops (Carrillo-Hermosilla et al., 2010; Kang et al., 2018; Seuring and Müller, 2008).

Second, suppliers and customers were also key partners as cooperation options in several configurations. Regarding suppliers (vertical relations), the results are coincident with previous research, which already demonstrated the importance of engaging these relations to develop new products and processes (Seuring and Müller, 2008; Tomlinson, 2010). On the other hand, relations with customers are not frequently mentioned as an explanatory factor in green innovation studies.

However, our findings also suggest that some types of external relations are relevant and positive for several combinations but are irrelevant or negative for others, showing an asymmetric effect. This could be the case for customer cooperation, which is absent in some configurations. More importantly, competitors and consulting entities have diverse relevance as, depending on the configuration and its combination with other factors, they are present or absent. These findings could contradict those of some previous studies (Boari et al., 2003, 2017; Tomlinson, 2010; Bergquist and Söderholm, 2011).

Additionally, following Fiss et al. (2013) and Meuer and Rupietta (2017), we have also conducted complementary analyses that are available in the Appendix B. This approach might serve both as a robustness check and to address one of the shortcomings associated to the use of QCA, which is related to the limitations around the number of variables included in the model. In particular, we performed a logit regression, regressing each path with respect to the GI outcome including several control variables in the analysis. The complementary analysis performed confirms the results obtained with the QCA method. Furthermore, we calculate statistically significant differences across paths in relation with internal-to-the-firm endowment of resources for innovation, to identify if any of the path is more likely to be associated to specific types of firms. Such an additional analysis, reported in Tables B.1 and B.2, provides additional nuances in the understanding of the equifinal paths, suggesting that some combinations of external partners might be more effective than others in complementing the internal innovative effort of the firm.

6. Conclusions

This research has tried to disentangle the combinations of external collaborations as a key particularity of environmental innovative performance and, moreover, to explore the conditions in which they might best fit. To accomplish this objective, we have applied a complex causality approach (Meyer et al., 1993), using the QCA technique on CIS data from the Spanish Technological Innovation Panel (PITEC). Using csQCA, the causal complexity of the phenomenon was studied via both necessity and sufficiency analyses (Ragin, 2008). First, a necessity analysis was performed to determine whether the presence or absence of any of the conditions studied was necessary to belong to the set called, in our case, green innovators. Second, a sufficiency analysis was conducted to detect those conditions, or combinations of them, that were potentially sufficient to yield the same green innovation output. Our results empirically assess the complex causality of the studied phenomenon, showing a great number of options for companies to develop GI via external collaborations.

This paper bases its scientific value on the potential advances regarding theory, methods, and practice. With respect to theory, our research effort contributes to the literature on green innovation by considering the conjoint effect of several external relations as alternative innovation enablers, moving beyond the linear approach recurrent in extant contributions that studied individual effects of separated or isolated variables (e.g., De Marchi and Grandinetti, 2013; Ghisetti et al., 2015; Marzucchi and Montresor, 2017; Martínez-Cháfer et al., 2021; Awan et al., 2021). Accordingly, we reconcile some previous partial and, sometimes, contradictory contributions on this issue, indicating the existence of multiple, equifinal pathways for firms to develop green innovations. In conclusion, we support the idea of the critical importance of external relational resources for innovation (Cassiman and Veugelers, 2006) but contribute important nuances to effectively assess it considering for the variety of innovation strategies.

Methodologically, this paper represents a pioneering effort by using a configurational approach to study the engagement in collaboration on innovation in the context of GI. While this configurational approach has recently been used in the literature on general innovation (Martínez-Cháfer et al., 2021), this is the first time that is focusing on GI, which are

Table 5
Path analysis.

Path	Presence of conditions	Absence of conditions	Analysis – foundations of the conjoint effects	References
1	Universities and RC	KIBS	The combination of the presence of institutional cooperation and the absence of cooperation with knowledge-intensive actors may respond to substitute effect that these two antecedents may have. A great portion of the companies seem to find motivating to engage with institutions with knowledge intensive capabilities as a substitute of consulting services.	(Bossink, 2007*; De Marchi, 2012*; De Marchi and Grandinetti, 2013*;Molina-Morales and Martínez-Cháfer, 2016; Norberg-Bohm, 2000*; Pinto et al., 2015; Tether and Tajar, 2008©)
2	Universities and RC suppliers		In this particular path companies seem to benefit from the complementarity of the knowledge provided from both actors. Motivations may range from the actual benefit of the two combined sources of knowledge or as a response to calls for innovation projects that require the participation of these type of partners together.	(Andersen, 1999*; Bossink, 2007*; Cainelli et al., 2012*; Cuerva et al., 2014*; De Marchi, 2012*; Geffen and Rothenberg, 2000*; Meyer et al., 2000©; Molina-Morales and Martínez-Cháfer, 2016; Norberg-Bohm, 2000*; Theyel, 2006*)
3	Suppliers customers		This particular path supports the importance of the supply chain integration to achieve superior environmental sustainability results. Indeed, companies may find it attractive to engage both upstream and downstream the suppy chain, specially if they are concerned to innovate for the circular economy.	(Andersen, 1999*; C. Bakker et al., 2014*; De Marchi, 2012*; Franco, 2017©*; Geffen and Rothenberg, 2000*; Gong et al., 2020©*; Hofstetter et al., 2021*; Meyer et al., 2000©*; Theyel, 2006*; Awan and Sroufe, 2020*)
4	Universities and RC Customers	Competitors	Continuing with the relevance of the relationships with universities and RC as a pivotal ingredient, this path highlights the interaction with another complementary source of knowledge: the customers. Companies innovating in areas related with the sustainability may try to close-loops in order to manage the end-to-life cycle of their products. To do so, it seems very convenient to complement both antecedents with the exclusion of potential opportunistic behaviour coming from competitors.	(Andersen, 1999*; Bossink, 2007*; De Marchi, 2012*; Geffen and Rothenberg, 2000*; Meyer et al., 2000©*; Molina-Morales and Martínez-Cháfer, 2016; Norberg-Bohm, 2000*; Theyel, 2006*)
5	Customers	Competitors KIBS	In this case, the combination also highlights the tendency to reject of both competitors and KIBS while relying on the engagement with customers. In fact, knowledge coming from the rejected ingredients may conflict with the valuable information that comes straight from the supply chain to enhance circular economy related processes.	(Andersen, 1999*; De Marchi, 2012*; Geffen and Rothenberg, 2000*; Meyer et al., 2000©*; Theyel, 2006*; Awan and Sroufe, 2020*)
6	suppliers Competitors KIBS		Although its raw coverage is the second smallest, it is interesting to see alternatives with different combinations of factors. This case is a clear antagonistic option to path 5. This path is probably a fit for sectors where opportunistic behaviours are not so likely to happen or in areas where policy makers foster the collaboration of these types of actors.	(Andersen, 1999*; Boari et al., 2017; De Marchi, 2012*; Geffen and Rothenberg, 2000*; Meyer et al., 2000©*; Theyel, 2006*; Tomlinson, 2010)
7	Universities and RC Competitors	Customers	The last path and the one with the less coverage represents the motivation of a reduced number of cases to combine knowledge from sources that in previous paths where rather discarded. It may respond again to specific cases where either the opportunistic behaviours are not contemplated, or the requirements of certain policy programmes incentivise to do so. Also rejecting the participation of customers in the recipe may respond to sectors where customers are not relevant or distant in the distribution channel to provide valuable feedback.	(Boari et al., 2003, 2017; Tomlinson, 2010; Norberg-Bohm, 2000*, Bossink, 2007*; Molina-Morales and Martínez-Cháfer, 2016; De Marchi, 2012*)

Note: The references outlined in this table correspond to studies about both innovation in general and GI (*). Also, these same references can apply to studies that analyse individual or conjoint effects (©) of the corresponding antecedents.

considered different from general innovations as far as cooperation is concerned (Cainelli et al., 2015; De Marchi, 2012). Addressing the questions of how broad and deep the net of external collaborators for GI should be (Juntunen et al., 2019), we unpack the configurations that integrate different types of partners.

Our results provide important contributions to practitioners' understanding of GI, as we outline potential recipes of collaboration activities that lead to the development of green innovations, with implications relevant for both policymakers and practitioners. As for policy makers, our results contribute to the design and implementation of regional or national policies aiming at prompting GI at firms' level, suggesting the importance to develop schemes (for example funding schemes) that support firms to cooperate with more than one typology of external partners for every given green innovative project. Additionally, it suggests the importance to avoid adopting a 'one-size-fits-all' approach, imposing firms which combinations of partners to collaborate with (e.g., suppliers and universities), but rather to offer for a limited number of alternatives. As for managers, the conclusions of the research can inspire to explore unknown alternatives for enhancing their green innovation performance, offering a benchmarking opportunity to identify how to overcome complexity of GI via collaboration. Indeed, our findings suggests several, detailed recipes that managers can follow to combine knowledge and capabilities of suppliers, customers, KIBS, universities or even competitors with the aim to successfully innovate and reduce environmental impacts. Further, they reveal the importance to evaluate new cooperation agreements for innovation also in view of the synergies they can create with respect to the existing portfolio of agreements.

The use of the QCA approach allowed us to provide interesting contributions to extant knowledge, however, it also presents some limitations and challenges. Most of the main drawbacks of the use of QCA come from the fact that it is sometimes used with databases that account for just a few cases (often fewer than 100). However, our database is large enough to overcome this common issue. On the other hand, in the case of csQCA, gradual assessment is often complicated due to the necessity of dichotomising all the factors. Another issue stems from the static nature of our analysis. The derived limitations of our QCA snapshot are, in any case, similar to what occurs with other analytical methodologies. Despite these potential limitations, the benefits of the QCA approach are still of capital importance and of great applicability for social science studies (Sehring et al., 2013). We further acknowledge other limitations of this effort, which may feed further directions for the research. First, we focused on technological green innovation only. However, better sustainability performance could be achieved via other forms of innovation, such as marketing or organizational, for which differential paths of collaboration could play a role. Using the same approach, future research might shed light on the configurations of external relations that foster other types of green innovations, including disentangling product from process innovations, and of the differences among innovation types, in lines with Hyll and Pippel (2016) or Cleff and Rennings (1999). The use of alternative, subjective measures for environmental innovations could inspire future replicative studies too. Self-reported data on environmental innovations, indeed, does not necessarily allow to capture for the effective reduction of environmental impacts that derives from the GI introduction. A means-ends decoupling (Halme et al., 2020) could affect GI effort, so that emissions or pollution reduction enabled by innovation might be lower than expected (Töbelmann and Wendler, 2020). Furthermore, caution should be used in generalizing results as we have focused just on one empirical context: Spain. A potential extension of this research could consider analysing other geographical contexts, to account for the impact of differences in regulatory frameworks, technological capacities, stakeholder pressures and more generally in nation-level institutions (Alonso-Martínez et al., 2020; Horbach et al., 2013; Ioannou and Serafeim, 2012). Indeed, further analysis could replicate this study using more recent data, to verify if patterns of collaboration might have changed over time. Finally, our QCA analysis presents contradictory configurations that have been separately characterised in the appendix. The analysis of these contradicting configurations can be very fruitful in future studies in order to disentangle the innovative mechanisms of this particular group of firms. Despite such limitations, we believe this contribution do open new research directions, pointing to the relevance to unpack collaboration dynamics to understand green innovation performance.

CRediT authorship contribution statement

Valentina De Marchi: Conceptualization, Formal Analysis, Validation, Writing – Original Draft, Writing - Review & Editing.

F. Xavier Molina-Morales: Conceptualization, Writing – Original Draft, Supervision, Funding Acquisition.

Luis Martínez-Cháfer: Conceptualization, methodology, Formal Analysis, Writing – Original Draft, Writing - Review & Editing, Visualization.

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Appendix A. Contradicting observations

Our analysis, as it is expected in large-N samples (Greckhamer et al., 2008, 2013), presents contradictions on some of the configurations found in our truth table. Following Ragin (2000) and Greckhamer et al. (2008), we have satisfactorily tested the statistical significance of the obtained paths and all of them pass the 0.8 benchmark (almost always sufficient) except for three that in any case pass very comfortably the 0.65 (usually sufficient). Consequently, and given that the main focus of this analysis is identifying configurations of cooperation activities that are suitable to develop environmental innovations, we have included the contradictory cases in our analysis. This is one of the four options that Rihoux and De Meur (2009) outline in order to cope with these contradictions. However, including them in the analysis does not clarify their contradicting condition. In this sense, Rihoux and De Meur (2009) suggest to analyse and interpret these cases involved in contradicting configurations separately from the actual csQCA procedures.

To do so, in this section we have identified and analysed the cases that cause the contradictions on some of the configurations. The number of cases that are the subject of this complementary analysis is 233 (4.9 % of the total). Among the main reasons that are subject to cause the contradictions in QCA, we can find measurement errors, randomness, coding mistakes, or inappropriate case selection (Greckhamer et al., 2013; Ragin, 2000). The first characteristic that we have analysed is the activity that the companies included in the contradicting group do. As it can be seen in Figs. A.1 and A.2, the distribution of activities in the contradicting group is very skewed towards the right-hand side of the histogram that corresponds to Knowledge Intensive Business Services (KIBS) companies (Miles et al., 1995).

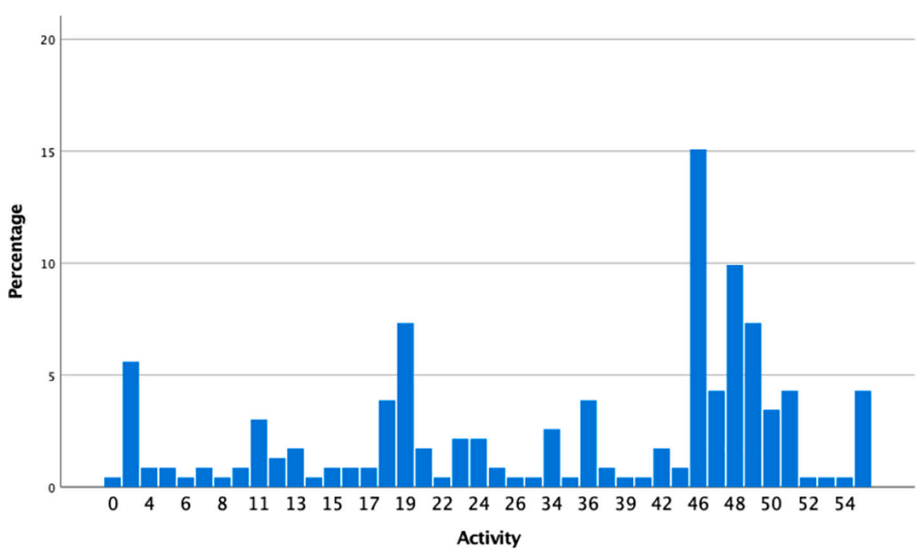

Fig. A.1. Contradicting cases, by industry.

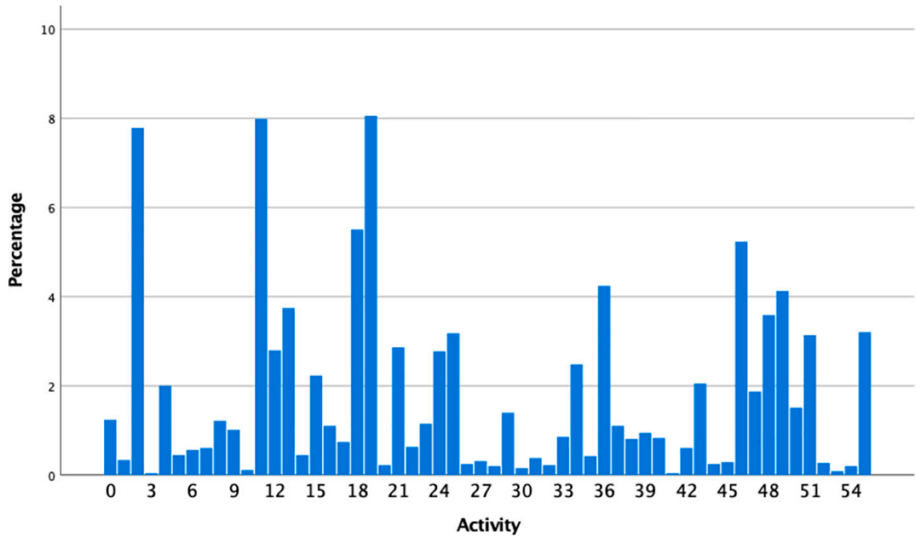

Fig. A.2. Non-contradicting cases, by industry.

Additionally, we have also investigated further properties of the companies to find out if there are other characteristics that showed significant differences. In this line we have performed some ANOVA tests that show significant results for the relationships with universities and research centres, internal expenditure on R&D, external expenditure on R&D and expenditure on the acquisition of new technologies and machineries enabling innovation (Table A.1). Indeed, analysing the cooperation profile, the companies that represent contradicting cases have a strong tendency to be related with universities and research centres. In fact, 88 % of the 233 cases have relationships with this type of actor while for the rest of the companies in our analysis this percentage is much lower, representing a 26 %.

Table A.1
Anova tests for contradicting vs. non-contradicting cases.

	Contradicting	Non-contradicting	Sig.
Cooperation with universities and RC	88 %	26 %	***
Internal R&D expenditure	64.07	57.158	**
External R&D expenditure	9.49	7.22	*
Expenditure on machinery et al.	3,90	7.88	***
Observations	233	4452	

Note: *** significant at 1 % level, ** significant at 5 % level, * significant at 10 % level.

In sum, contradicting cases represent a peculiar type of company that belongs primarily to KIBS industries, investing heavily in both internal and external R&D. Such results are consistent with the literature suggesting peculiarities of KIBS industries when it comes to innovation (Cainelli et al., 2020; Parrilli and Radicic, 2021). The results obtained by these contradicting cases provide very interesting food for thoughts to perform further studies as we mention in the future lines of research in the conclusion section.

Appendix B. Complementary analysis

In order to complement our QCA analysis and given the fact that our large-N sample allows us to do so, we have also performed a complementary analysis based on a logit regression. Following suggestions by Fiss et al. (2013) and Meuer and Rupietta (2017) we provide a further analysis complementing the QCA results with regressions analysis. We included several control variables, reporting on internal to the firms' resources for innovation and capturing industry effects. Following the seminal contribution by Cainelli et al. (2015) focusing on internal and external resources for innovation, we have included the dummy variables R&D, to control for intramural investments in R&D; TRAINING, to capture for firm's effort to increase employees' capabilities for innovation; and EQUIPMENT, to capture for the acquisition of new technologies and machineries enabling innovation. Furthermore, we have added the variable SIZE (measured as the natural logarithm of firms' employees) to control for eventual differences in the stock of resources and capabilities available at firm's level and in the stakeholders' scrutiny (Klewitz and Hansen, 2014; del Río González, 2009). Finally, we have included dummies to capture for industry specificities, using the EU classification based on their technological intensity[4], four related to manufacturing industries (distinguishing High-technology vs Medium-high tech vs Med-low tech vs Low tech manufacturing), two related to service industries (Knowledge intensive vs Less Knowledge Intensive services) and one reporting on other sectors (agricultural and extractive industries).

Table B.1 reports the results of the logit regression performed, using as dependent variables the outcome variable used in the QCA analysis. In our case, the dependent variable is having successfully introduced in the market an environmental innovation; and as independent variables dummy variables reporting if firms belong to the PATH obtained via the QCA analysis. Following suggestions in Meuer and Rupietta (2017), we overcome the possibility of multicollinearity for configurations being structurally similar by running multiple regressions separately for each configuration (models I to VII in Table B.1). Overall, results are consistent with our initial findings suggesting the significant roles of the configurations identified in spurring superior green innovation performances, providing further confidence in our results.

[4] See https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an2.pdf for details

Table B.1
Logit models predicting introduction of green innovation.

	Outcome (green innovation)													
	Model I		Model II		Model III		Model IV		Model V		Model VI		Model VII	
	COEF	S.E.	COEF	S.E.	COEF	S.E.	COEF	S.E.	COEF	S.E.	COEF	S.E.	COEF	S.E.
PATH1	0.52***	(0.095)												
PATH2			1.30***	(0.140)										
PATH3					1.35***	(0.164)								
PATH4							0.85***	(0.171)						
PATH5									0.61***	(0.152)				
PATH6											1.79***	(0.315)		
PATH7													0.48**	(0.237)
Size	0.10***	(0.022)	0.07***	(0.022)	0.08***	(0.022)	0.10***	(0.022)	0.10***	(0.022)	0.09***	(0.022)	0.10***	(0.022)
R&D	1.21***	(0.072)	1.17***	(0.071)	1.20***	(0.071)	1.24***	(0.071)	1.26***	(0.071)	1.25***	(0.071)	1.28***	(0.071)
Equipment	0.27***	(0.096)	0.21**	(0.098)	0.24**	(0.098)	0.26***	(0.097)	0.27***	(0.096)	0.25***	(0.097)	0.27***	(0.096)
Training	0.53***	(0.106)	0.47***	(0.108)	0.47***	(0.107)	0.50***	(0.107)	0.51***	(0.106)	0.51***	(0.106)	0.53***	(0.105)
HIGHTECH_MANUF	0.17	(0.168)	0.21	(0.170)	0.15	(0.170)	0.13	(0.169)	0.13	(0.169)	0.18	(0.170)	0.16	(0.169)
MEDHTECH_MANUF	0.07	(0.136)	0.10	(0.137)	0.04	(0.137)	0.04	(0.136)	0.04	(0.136)	0.07	(0.137)	0.06	(0.136)
MEDLTECH_MANUF	0.01	(0.141)	0.04	(0.142)	0.02	(0.142)	0.00	(0.141)	0.01	(0.141)	0.03	(0.142)	0.01	(0.141)
LOWTECH_MANUF	−0.29*	(0.154)	−0.28*	(0.155)	−0.33**	(0.155)	−0.32**	(0.154)	−0.33**	(0.154)	−0.30**	(0.155)	−0.31**	(0.154)
KI_SERVICE	−0.74***	(0.131)	−0.73***	(0.132)	−0.79***	(0.133)	−0.75***	(0.131)	−0.74***	(0.131)	−0.73***	(0.132)	−0.71***	(0.131)
LESSKI_SERVICE	−0.49***	(0.150)	−0.45***	(0.152)	−0.49***	(0.151)	−0.50***	(0.150)	−0.50***	(0.150)	−0.48***	(0.151)	−0.49***	(0.150)
Constant	−0.46***	(0.158)	−0.34**	(0.157)	−0.33**	(0.157)	−0.41***	(0.157)	−0.43***	(0.157)	−0.36**	(0.158)	−0.42***	(0.157)
Observations	4685		4685		4685		4685		4685		4685		4685	
Wald Chi(2) test	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
Pseudo R-squared	0.106		0.119		0.116		0.105		0.103		0.109		0.101	

Additionally, following the approach in Meuer et al. (2015), we seek in a second step to explore whatever these configurations show some differences in terms of internal-to-the-firm endowment of resources, using the same firm level variables adopted to calculate the regression analyses. Table B.2 shows the result, reporting the average values of the variables considered for all the seven paths. The last column shows the results of the Chi2 (or one sample *t*-test, for the continuous variables) indicating the statistical difference across the paths. Please note that, considering that the 7 paths are not independent, we have calculated the tests just on the firms that belong to one unique path; the average values, however, have been calculated for the overall sample of firms that belong to that path.

Table B.2
Descriptive statistics (means) across the different configurations.

	Path1	Path2	Path3	Path4	Path5	Path6	Path7	Sig.
Size	4.61	5.15	5.02	4.52	4.29	5.33	4.81	**
R&D	90.7 %	91.1 %	90.4 %	93.2 %	88.5 %	87.4 %	90.7 %	***
Training	23.7 %	28.1 %	28.5 %	31.7 %	27.0 %	24.1 %	16.7 %	***
Equipment	21.1 %	28.5 %	25.0 %	24.8 %	19.0 %	27.6 %	25,9 %	***

Note: *** significant at 1 % level, ** significant at 5 % level.

Appendix C. Variable construction and calibration

In this section of the appendix, we explain how the variables used in the QCA analysis were obtained and calibrated.

Outcome: green innovation

The outcome green innovation was measured choosing two environmental related items of the following generic question of the PITEC survey: "*Objectives of the technological innovation in the last 3 years*". The two items related to the environmental objectives when implementing technological innovations are these:

o Reduced environmental impact
o Compliance with environmental, health or safety regulatory requirements

The scale of the items for this survey question ranges from 1 to 4 being this last value the one with more intensity in relation with the importance of the objective for the company. To dichotomize the variable to be used in the csQCA analysis we assign a value of 1 when the sum of objective 11 and 13 was 4 or more and 0 otherwise.

Conditions: cooperation with suppliers, customers, competitors, consulting, universities and research centres

In the PITEC survey there is a specific section that is related to *Cooperation for technological innovation activities in the last 3 years.* In this section there's a question that urges to *indicate the type of partner you cooperated with and the country where it is located.* To dichotomize our corresponding conditions, we assigned the value of 1 when the type of partner was selected, regardless the country, and 0 otherwise.

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