


## Article

# The Effect of Open Innovation on Eco-Innovation Performance: The Role of Market Knowledge Sources

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**Abstract:** Organizations use multiple strategies to increase the number and impact of eco-innovations as a path to achieve competitive advantage. In this article, we study the role of open innovation activities, specifically related to market sources, as a driver of eco-innovation performance. While studies have looked at the relationship between these two emergent innovation phenomena from a broad perspective, we explore whether specific market knowledge sources—clients, suppliers, competitors, and consultants—and their combined use—affect eco-innovation performance. We rely on insights from theories of open innovation and sustainable and environmental innovation to build a theoretical framework about the determinants of eco-innovation performance from a market-driven open innovation perspective. Our sample consists of 3047 firm-year observations obtained from three consecutive panels of the Chilean Innovation Survey (2009–2014). We found that clients, suppliers, competitors, and consultants as knowledge sources positively influence eco-innovation performance in firms. In addition, our results suggest that a combination of client sourcing with supplier and consultant sources of knowledge positively affect eco-innovation performance. We discuss the implications of our findings for open innovation activities on eco-innovation and suggest ideas for future research.



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**Keywords:** eco-innovation performance; open innovation; market knowledge sources; technological eco-innovation; business sustainability strategy

## 1. Introduction

The changing and complex nature of the current business context has positioned innovation as a cornerstone of a firm's long-term competitive advantage [1,2]. In recent years, the increasingly visible effects of climate change, the ecological aspects of infectious diseases (e.g., the Ebola and Cholera crisis in Africa and more recently the COVID-19 pandemic), the degradation of ecological systems, and the higher expectations of customers in relation to the role of business in society, have dramatically increased corporate awareness about the importance of developing innovations capable of connecting the firm's strategy with environmental value creation [3,4]. Moreover, there is growing evidence that organizations that implement environmentally-driven innovations—better known as eco-innovations—can improve their financial performance and strengthen their competitive position (i.e., doing well by doing good) [5–8]. Therefore, in order to develop stronger competitive strategies, firms—either large, medium or small—must understand what can drive successful eco-innovation.

Eco-innovation refers to “the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives” [9] (p. 122). Eco-innovation has been used as a synonym for “environmental innovation”, “green innovation,” and “sustainable innovation” depending on the author and the outlet where the research is

published [10]. In this study, we follow the lines of previous studies and consider eco-innovation as interchangeable with the three concepts previously mentioned—as long as their use is consistent with or similar to Kemp and Pearson’s definition [9]. In addition, it is important to note that eco-innovation performance encompasses a wide range of environmental impacts, including material use, energy use, water pollution, and CO<sub>2</sub> emissions, among others [11]. Thus, it includes—but is not limited to—eco-efficiency (one of the most used terms to study eco-innovation performance).

Previous literature has identified different drivers of eco-innovation, including regulation pressures, corporate strategy, technological availability, and collaborative activities between stakeholders [10–14]. Due to the complex nature of environmental value creation [15], scholars have recognized that eco-innovation needs information to be gathered from outside the firm’s boundaries [5,16]. Thus, how firms organize their time and resources to collaborate with stakeholders has become a strategic challenge [17]. Firms can respond to this challenge by adopting an open innovation model, which embraces the integration of complex external knowledge to create innovations that are beneficial both for the firm and the system wherein they participate.

Open innovation is defined as “the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively” [18] (p. 1). Open innovation includes both inbound (utilization of external sources) and outbound (external use of a firm’s knowledge) flows of knowledge to boost innovations [19,20]. An increasing number of studies have probed the effective role of open innovation in creating eco-innovation, which entails a greater focus on inbound strategies (i.e., the more external knowledge sources a firm uses, the better eco-innovation results they obtain) [5,14,16,21]. The sources utilized by organizations to implement inbound open innovation strategies can be institutional, professional, and market-driven [22]. However, extant research has primarily focused on aggregated open innovation strategies, with a lack of theorizing about what particular sources can stimulate organizations to improve eco-innovation performance.

Of all external sources used by organizations in open innovation activities, market-driven sources are essential to implement eco-innovations [12], because collaboration with different stakeholders is necessary to develop a business strategy aimed at creating environmental and/or social value [3,23]. When eco-innovation is part of the firm’s strategy, the interests of different stakeholders are somewhat integrated in the value proposition [24]. Thus, the market can be more open to engage in collaboration and provide crucial information to both design and sustain this form of innovation over time [25]. Unfortunately, we still know little about the role of different market sources in eco-innovation performance. We address this gap by answering the following question: what market knowledge sources relate to eco-innovation performance? In so doing, we investigate the effect of individual market categories, namely clients, suppliers, competitors, and consultants [26], and explore how each might enhance organizations’ eco-innovation performance.

We also explore whether diverse combinations of collaborative relationships can have additive or subtracting effects on eco-innovation performance, which is essential to understand how organizations organize the array of inbound knowledge sources to help transform ideas into new products and processes. The literature on this topic has demonstrated that specific interactions between external sources can have complementary consequences on the production and adoption of technological innovations [27]. However, there is scarce knowledge about the combinations of external knowledge that positively interact to enable eco-innovation. We propose that the joint use of different market sources can help organizations with these efforts. Thus, we test what combination of client and other market sources can best promote eco-innovation in firms.

The main aim of this research is to understand the effect of individual and combined market sources on eco-innovation performance. By doing this, we expect to make three contributions. First, previous studies have found a positive relationship between open innovation activities and eco-innovation at an aggregate level [14,21,26,27]. We contribute to

strengthening the theoretical bridge between these two streams of innovation literature by distinguishing between specific market forces and their positive impact on eco-innovation performance. Second, although evidence of complementarity between different external sources on innovation performance has been studied [28], our research adds further evidence about the positive joint effect of market sources specifically on eco-innovation. We examine how a firm that relies on information coming from their clients can better utilize that information for implementing eco-innovations when, at the same time, organizations count on other external information coming from suppliers and consultant sources. Third, from a practitioner perspective, this study provides evidence-based knowledge for managers who seek to create eco-innovations that enhance the competitive position of the firm. We propose that companies can strategically use different market sources to identify and create innovations aimed at enhancing a value proposition based on environmental or ecological attributes.

In the next section, we develop hypotheses and provide theoretical justifications for the relationship between market knowledge sources and eco-innovation effects. This is followed by the description of the data and sample, analytical method, and statistical results. We discuss the implications of our study for research on the relationship between open innovation strategies—focusing on market factors—on eco-innovation performance. We highlight the importance of combining client knowledge sources with external information from other markets. The paper ends by listing the study's limitations and our concluding remarks.

## 2. Theory and Hypotheses

### 2.1. Market Knowledge Sources on Eco-Innovation

Innovation scholars have recognized the relevance of organizations' capability to access market sources that would provide new resources and ideas to innovate successfully [22,29]. For example, firms pursuing the development of eco-innovations will likely face technological problems that require a breadth of knowledge that is difficult to find within the boundaries of the company [30]. Four market sources that have been positively associated with boosting innovations are clients, suppliers, competitors, and consultants, which provide different but complementary knowledge for both value creation and value capture [31,32].

Collaboration with clients is essential for increasing the flow of knowledge—to the firm—that helps to enhance the value proposition as well as the process of value capture [11, 33]. Von Hippel [31], for example, has emphasized the importance of clients in developing successful technological innovations, as clients provide useful information about their needs and preferences. Similarly, clients can push to create new processes that enhance customers' experience and increase their satisfaction with the firm [34,35]. In the case of eco-innovations, clients' willingness to pay will depend on the direct benefits they can get from these types of innovations, which can range from the betterment of product and services to the enhancement of individuals' self-image or social identity [36–38]. Finally, clients can be one step ahead regarding environmental expectations (especially younger generations and citizens from developed countries) and, consequently, can offer useful information about future needs and trends.

Suppliers can contribute to the refinement and improvement of new products [39,40], or to the improvement of a firm's processes to achieve higher levels of efficiency and effectiveness. For example, firms can work closely with suppliers to develop new technologies embedded in the production process [41], propose new materials or components that can improve the quality of products and services [42], and conduct joint search activities aimed at improving the efficiency of product elaboration and even the whole supply chain [38]. Strategically, collaboration with suppliers is mostly important for the process of value creation [43,44], as eco-innovations driven by this market source are primarily oriented to manage the risks of the value chain, increase efficiency, and differentiate products [8].

Compared with other types of innovations, eco-innovation usually requires firms to collaborate even with competitors [25], as the goal is not only economic performance, but the creation of positive environmental impact [3]. In this case, successful collaboration with competitors is based on a shared vision of the future, where the betterment of the ecological environment is considered a necessary business practice and even an ethical obligation [45–47]. Although an eco-innovation strategy works better with collaborative interactions, open innovation with competitors is not always based on collaboration and usually involves the imitation of new processes and products/services [48]. Collaborating with competitors can impact both value creation and value capture, depending on the nature of the relationship and the knowledge that is shared by firms [49–51].

Finally, consultants can provide information related to processing knowledge—specific to the firm—that is obtained indirectly from competitors and other relevant stakeholders [52,53]. In the case of eco-innovations, firms can get systematic knowledge and a variety of information from other industries that face similar environmental challenges [21]: governmental agencies that drive environmental regulations [54], and NGOs that are devoted to creating a positive environmental impact in the communities in which the firm operates [55], among others. Due to the breadth of knowledge than can be obtained from consultants, collaboration with them can be useful for both value creation and value capture, depending on the nature of the relationship and the services that are required by the firm.

Based on the arguments presented above, we hypothesize:

**Hypothesis 1 (H1a):** *Client knowledge sources are positively associated with eco-innovation performance.*

**Hypothesis 1 (H1b):** *Supplier knowledge sources are positively associated with eco-innovation performance.*

**Hypothesis 1 (H1c):** *Competitor knowledge sources are positively associated with eco-innovation performance.*

**Hypothesis 1 (H1d):** *Consultant knowledge sources are positively associated with eco-innovation performance.*

## 2.2. Combined Market Knowledge Sources on Eco-Innovation

Managers who seek useful knowledge from different stakeholders need to avoid spending valuable time and financial resources targeting external sources that provide duplicated information [56,57]. To create an effective open innovation strategy, firms need to work closely with different external sources to create synergies that enhance the likelihood of achieving successful innovations [58]. The literature on open innovation stresses the need to seek complementary information from different or distant pairs of sources, such as the use of internal and external sources for boosting process innovation [59]. Positive interactions can also arise from pairs of external sources close to each other that are differentiated by key attributes, such as the positive effect of collaborating with scientific and supply-chain partners to make product innovation [17]. Therefore, we propose that combining knowledge from complementary market sources has a positive effect on eco-innovation performance.

From the four market sources discussed previously, clients' needs and requirements are usually at the center of any innovation intention. The client's perspective is important because it informs the essence of the value proposition [33], which can be enriched and enhanced by adding the viewpoint of suppliers, competitors, and consultants. By gathering information about the customer's needs, as well as their view (or desire) of a better future regarding environmental and green issues, the firms can transform these ideas on specific eco-innovations that would help to sustain a competitive performance.

By combining the information provided by clients with insights coming from suppliers, firms can connect streams of knowledge from the two extremes of the value chain [60,61]. Thus, managers may integrate pull-force needs that shed light on improvements in value proposition/capture (the client perspective) with push-forces that can help to create new processes or use emergent materials that could match customers' environmental needs (i.e., value creation) [62]. Similarly, managers may compare and contrast customer feedback about green aspirations and demands with competitors' practices regarding eco-innovations, as well as consultants' knowledge about environmental needs, environmental regulations, and industry benchmarks. This type of analysis can offer firms strategic insights to introduce a greater number and variety of eco-innovations, especially if the knowledge coming from the different market sources can be complemented to improve both value creation and value capture.

Finally, another dimension by which firms achieve synergies in their search strategies is by combining more tacit and explicit knowledge [63] with theoretical knowledge [52]. This synergy is achieved by using, in particular, client and consultant knowledge sources. Firms looking for positive performance on eco-innovations can learn from different customer expectations about what would make an organization a leader in environmental performance in its industry (i.e., experienced-based knowledge) and combine this information with theoretical frameworks and organized knowledge about eco-innovation trends and practices provided by consultants. This search strategy might also work with the other two collaborative pairs (i.e., client-supplier and client-competitor), but to a lesser degree, as suppliers and competitors primarily offer experienced-based knowledge.

Based on the arguments presented above, we offer a second set of hypotheses:

**Hypothesis 2 (H2a):** *There is a complementary effect between client and supplier knowledge sources on eco-innovation performance.*

**Hypothesis 2 (H2b):** *There is a complementary effect between client and competitor knowledge sources on eco-innovation performance.*

**Hypothesis 2 (H2c):** *There is a complementary effect between client and consultant knowledge sources on eco-innovation performance.*

### 3. Methods

#### 3.1. Data and Sample

We empirically examine our hypotheses using data from the Chilean Innovation Survey, administered by the Ministry of Economy [26]. Chile is the only country in South America that is a member of the Organization for Economic Co-operation and Development (OECD), so the design and methodology of the Chilean Innovation Survey follows the guidelines suggested by the OECD's Oslo Manual (2005) and it is similar to the Eurostat Community Innovation Survey [64]. The Chilean Innovation Survey has been implemented every two years since 1995. Thus far, the results from nine panels have been published based on samples covering 95% of statistical representativeness regarding the distribution of companies by regions of the country (national representativeness), economic sector (economic activity representativeness), and the size of companies according to annual sales defined by the Ministry of Economy.

To conduct this study, we had access to four consecutive waves of the Chilean Innovation Survey from 2011 to 2017. However, the 2017 survey has several differences compared with the other three panels and had incomplete information about the independent variables that we used in this study. For consistency, we included the first three panels in constructing our sample, covering the 2009–2014 period.

To build our dataset, we matched the questions for each survey to create the longitudinal dataset. A total of 2841 unique organizations responded to at least one of the three surveys. The total of organizations in our sample accounts for a total of 3047 firm-year



observations (hereafter, observations). The industry distribution primarily includes manufacturing (25.9%), construction (15.8%), retail commerce (11.7%), transportation and storage (8.14%), building (7.52%), health services (5.97%), agriculture (5.12%), and financial and insurance services (4.17%). Finally, the firm size distribution, based on sales information provided to the Chilean Ministry of Economy, is 52.0% small firms, 22.8% medium firms, and 25.2% large firms.

### 3.2. Measures

#### 3.2.1. Dependent Variable—Eco-Innovation Performance

The survey asks firms to indicate whether they had introduced product or process innovations that had a positive environmental impact in the last two years. The scale ranges from 0 to 4, where zero means no environmental impact from innovations implemented and four means a high positive environmental impact. We measured eco-innovation performance for each firm in each panel year (a period) by normalizing the variable, which implies dividing it by the highest eco-innovation performance the firm could potentially achieve (=4). Thus, the resulting variable takes values from 0 to 1 [65].

#### 3.2.2. Independent Variable—Market Knowledge Sources

The survey includes four market knowledge sources: suppliers, clients, competitors, and consultants. Respondents are asked to use a Likert scale (1 = very important; 2 = important; 3 = some importance; 4 = not important at all/not used) to evaluate the importance of each of the four market sources to their firm's innovation activities. We assigned a binary value to reflect the importance of each external knowledge source for the firm [66]. Survey responses of 'very important' or 'important' received a value of 1; whereas survey responses of 'some importance' or 'not important at all/not used' received a value of 0. The use of binary values helps to alleviate the potential measurement error so an ordinal Likert scale cannot be interpreted as an interval scale [67]. Therefore, we measured Client Knowledge Sources, Supplier Knowledge Sources, Competitor Knowledge Sources, and Consultant Knowledge Sources for each firm in each panel year, as a dummy variable, setting it at one if the organization significantly employed those external sources in the last two years, and zero otherwise.

#### 3.2.3. Control Variables

We used nine control variables that could influence eco-innovation performance. First, previous studies suggest that firm size is significantly associated with innovation performance [68]. We measured size as the number of employees, expressed as a natural logarithm. Second, organization ownership (public or private) may be related to its innovative behavior [69]. We measured public owned as a dummy variable, setting it at 1 if the organization is totally or partially government owned, and 0 otherwise. Third, organizations located in metropolitan areas can be more aware of the relationship between firms' environmental consequences and competitive advantage. We measured metropolitan as a dummy variable, setting it at 1 if the organization is located in a metropolitan area, and 0 otherwise. Fourth, a firm that is a member of a firm group can take advantage of innovations developed by other members [70]. We controlled for firm group and measured it as a dummy variable, setting it at 1 if the organization is part of a group of firms, and 0 otherwise. Fifth, firms participating in foreign markets would be able to take advantage of specialized knowledge located in the host country [71]. This can be particularly relevant for eco-innovation outputs. We measured international as the percentage of the firm's exports of its total revenue. Sixth, similar to organizational size, organizational age has also been deemed to be associated with the firm's innovativeness [72]. We controlled for entrepreneurial firm and measured it as a dummy variable, setting it at 1 if organizational age is equal to or less than 4 years, and 0 otherwise. Seventh, in addition to external knowledge sources, internal knowledge sources can also stimulate innovation [57]. The survey includes only one item to specify internal sources. Respondents have four choices

and are asked to use a Likert scale (1 = very important; 2 = important; 3 = some importance; 4 = not important at all/not used) to evaluate the importance of internal knowledge sources to innovation activities. To calculate the value of internal knowledge sources for each firm, survey responses of either ‘very important’ or ‘important’ received a value of 1; survey responses of either ‘some importance’ or ‘not important at all/not used’ received a value of 0. Eighth, the industry technological and competitive domain affects the innovativeness of firms in which it is embedded [73]. Industry is a dummy variable to account for industry differences. Thirteen industries are included in the sample: manufacturing, mining, services, building, retail, transportation and storage, information and communications, financial and insurance activities, agriculture, fishing, health services, real estate activities, and other social services. Finally, we controlled for differences in the propensity to eco-innovate in any given period by using a variable entitled year.

### 3.3. Analysis

We analyzed data using the generalized estimating equations (GEE) technique for data analysis because GEE is appropriate: (1) for panel data like ours where variables from different time periods might be correlated [74,75], and (2) where the dependent variables are bounded between 0 and 1 [76]. To implement this estimation selection, we used the GEE with a binomial family, logit link function, and robust standard errors clustered by organization [77].

## 4. Results

Descriptive statistics and correlations for all the variables included in our analyses are presented in Table 1. On average, 23% of the companies participate in international markets, and 43% are members of a group of firms. In addition, 42% of organizations are located in metropolitan areas and 10% can be considered entrepreneurial firms. Among all market knowledge sources, supplier external sourcing is that most used by organizations in the sample (mean 0.54), followed by client and competitor sources (0.52 and 0.37, respectively), and finally by consultant knowledge sources (0.29).

**Table 1.** Descriptive Statistics.

| Variable                        | Mean | s.d. | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8    | 9    | 10   | 11   |
|---------------------------------|------|------|-------|-------|-------|-------|-------|-------|-------|------|------|------|------|
| 1 Eco-Innovation Performance    | 0.60 | 0.31 |       |       |       |       |       |       |       |      |      |      |      |
| 2 Size                          | 4.49 | 1.83 | 0.04  |       |       |       |       |       |       |      |      |      |      |
| 3 Public Owned                  | 0.01 | 0.10 | 0.03  | 0.14  |       |       |       |       |       |      |      |      |      |
| 4 Metropolitan                  | 0.42 | 0.49 | −0.07 | 0.16  | 0.03  |       |       |       |       |      |      |      |      |
| 5 Group                         | 0.43 | 0.50 | −0.03 | 0.37  | −0.08 | 0.11  |       |       |       |      |      |      |      |
| 6 International                 | 0.23 | 0.42 | 0.03  | 0.28  | 0.02  | 0.09  | 0.17  |       |       |      |      |      |      |
| 7 Entrepreneurial Firm          | 0.10 | 0.30 | 0.00  | −0.17 | −0.03 | −0.01 | −0.02 | −0.08 |       |      |      |      |      |
| 8 Internal Knowledge Sources    | 0.72 | 0.45 | 0.09  | 0.13  | 0.01  | 0.02  | 0.12  | 0.13  | 0.00  |      |      |      |      |
| 9 Client Knowledge Sources      | 0.52 | 0.50 | 0.14  | −0.02 | 0.00  | 0.00  | −0.02 | 0.03  | 0.02  | 0.27 |      |      |      |
| 10 Supplier Knowledge Sources   | 0.54 | 0.50 | 0.17  | 0.08  | 0.02  | 0.02  | 0.03  | 0.01  | 0.01  | 0.18 | 0.33 |      |      |
| 11 Competitor Knowledge Sources | 0.37 | 0.48 | 0.11  | 0.01  | 0.01  | 0.00  | 0.02  | 0.02  | 0.03  | 0.19 | 0.40 | 0.26 |      |
| 12 Consultant Knowledge Sources | 0.29 | 0.46 | 0.13  | 0.16  | 0.04  | 0.05  | 0.16  | 0.06  | −0.02 | 0.16 | 0.15 | 0.19 | 0.23 |

Number of observations 3047. Correlation coefficients greater than 0.03 or less than −0.03 are significant at  $p < 0.05$ .

Table 2 shows the regression results for eco-innovation performance based on a hierarchical analysis. We entered the control variables and external knowledge sources first (Model 1), followed by entering each market knowledge source individually (Model 2, 3, 4, and 5), and then entering all market knowledge sources all at the same time (Model 6). Finally, we included interaction effects between client knowledge sources and all the other market sources (Model 7, 8, and 9). We tested all models for multicollinearity by computing the variance inflation factors (VIFs). VIFs were between 1.04 and 4.59, below the recommended ceiling of 10 [78].

**Table 2.** Generalized Estimating Equations (GEE) Regression Results on Eco-Innovation Performance.

| Variable                            | Model 1             | Model 2             | Model 3             | Model 4             | Model 5             | Model 6             | Model 7             | Model 8             | Model 9             |
|-------------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Size                                | 0.03 *<br>(0.02)    | 0.04 *<br>(0.02)    | 0.03 +<br>(0.01)    | 0.04 *<br>(0.02)    | 0.03 +<br>(0.02)    | 0.03 +<br>(0.02)    | 0.03 *<br>(0.01)    | 0.04 *<br>(0.01)    | 0.03 *<br>(0.02)    |
| Public Owned                        | 0.29<br>(0.24)      | 0.27<br>(0.23)      | 0.27<br>(0.24)      | 0.28<br>(0.24)      | 0.25<br>(0.24)      | 0.23<br>(0.24)      | 0.27<br>(0.23)      | 0.27<br>(0.23)      | 0.24<br>(0.23)      |
| Metropolitan                        | −0.19 ***<br>(0.05) | −0.19 ***<br>(0.05) | −0.20 ***<br>(0.05) | −0.19 ***<br>(0.05) | −0.20 ***<br>(0.05) | −0.20 ***<br>(0.05) | −0.20 ***<br>(0.05) | −0.19 ***<br>(0.05) | −0.20 ***<br>(0.05) |
| Group                               | −0.09 +<br>(0.05)   | −0.08<br>(0.05)     | −0.09 +<br>(0.05)   | −0.09 +<br>(0.05)   | −0.12 *<br>(0.05)   | −0.11 *<br>(0.05)   | −0.08<br>(0.05)     | −0.09 +<br>(0.05)   | −0.11 *<br>(0.05)   |
| International                       | −0.02<br>(0.06)     | −0.02<br>(0.06)     | 0.00<br>(0.06)      | −0.02<br>(0.06)     | −0.02<br>(0.06)     | −0.01<br>(0.06)     | 0.00<br>(0.06)      | −0.02<br>(0.06)     | −0.02<br>(0.06)     |
| Entrepreneurial Firm                | 0.03<br>(0.08)      | 0.02<br>(0.08)      | 0.02<br>(0.08)      | 0.02<br>(0.08)      | 0.03<br>(0.08)      | 0.01<br>(0.08)      | 0.01<br>(0.08)      | 0.01<br>(0.08)      | 0.02<br>(0.08)      |
| Internal Knowledge Sources          | 0.27 ***<br>(0.05)  | 0.17 **<br>(0.05)   | 0.20 ***<br>(0.05)  | 0.21 ***<br>(0.05)  | 0.22 ***<br>(0.05)  | 0.11 *<br>(0.05)    | 0.15 **<br>(0.05)   | 0.16 **<br>(0.05)   | 0.15 **<br>(0.05)   |
| Industry                            | YES                 | YES                 | YES                 | YES                 | YES                 | YES                 | YES                 | YES                 | YES                 |
| Year                                | YES                 | YES                 | YES                 | YES                 | YES                 | YES                 | YES                 | YES                 | YES                 |
| Client Knowledge Sources            |                     | 0.33 ***<br>(0.05)  |                     |                     |                     | 0.18 ***<br>(0.05)  | 0.11<br>(0.07)      | 0.22 ***<br>(0.06)  | 0.24 ***<br>(0.06)  |
| Supplier Knowledge Sources          |                     |                     | 0.39 ***<br>(0.05)  |                     |                     | 0.28 ***<br>(0.05)  | 0.20 **<br>(0.07)   |                     |                     |
| Competitor Knowledge Sources        |                     |                     |                     | 0.27 ***<br>(0.05)  |                     | 0.09 +<br>(0.05)    |                     | 0.07<br>(0.09)      |                     |
| Consultant Knowledge Sources        |                     |                     |                     |                     | 0.35 ***<br>(0.05)  | 0.25 ***<br>(0.05)  |                     |                     | 0.19 *<br>(0.08)    |
| Client Sources × Supplier Sources   |                     |                     |                     |                     |                     |                     | 0.24 *<br>(0.1)     |                     |                     |
| Client Sources × Competitor Sources |                     |                     |                     |                     |                     |                     |                     | 0.16<br>(0.11)      |                     |
| Client Sources × Consultant Sources |                     |                     |                     |                     |                     |                     |                     |                     | 0.19 +<br>(0.1)     |
| Constant                            | 0.41 **<br>(0.13)   | 0.31 *<br>(0.13)    | 0.31 *<br>(0.13)    | 0.35 **<br>(0.13)   | 0.38 **<br>(0.13)   | 0.23 +<br>(0.13)    | 0.28 *<br>(0.13)    | 0.30 *<br>(0.13)    | 0.31 *<br>(0.13)    |
| Chi-Square                          | 133                 | 179                 | 198                 | 167                 | 177                 | 252                 | 225                 | 192                 | 215                 |

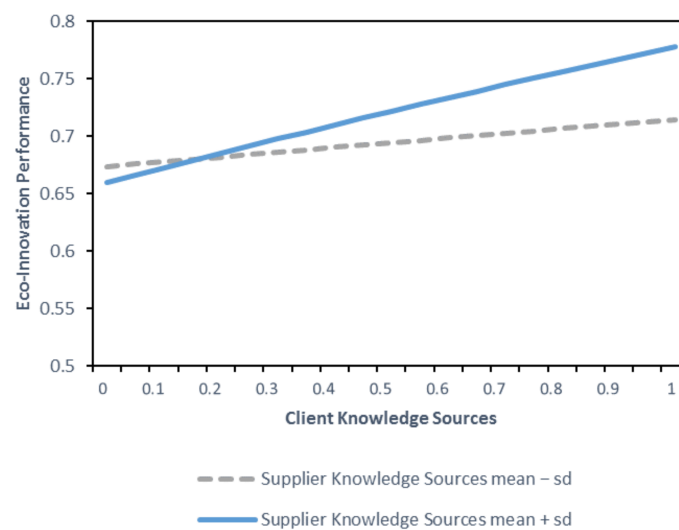
Number of observations 3047. +  $p < 0.10$ , \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ , based on two-tailed tests and clustered at the organizational level.

### Testing Hypotheses

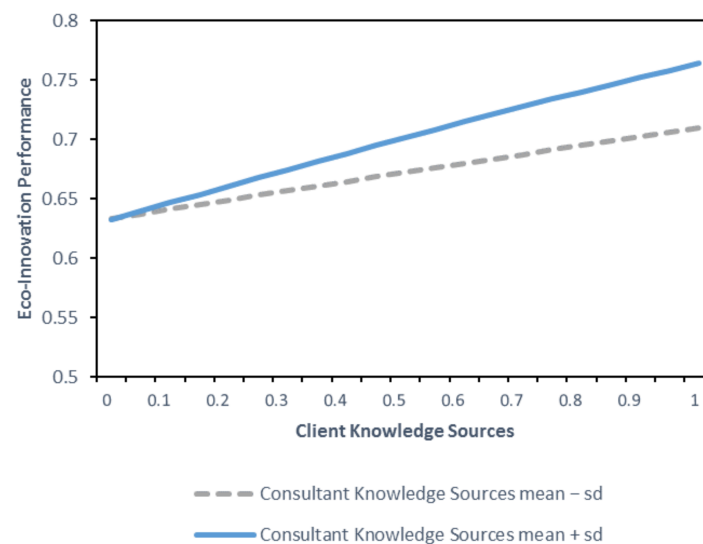
H1a proposed that the effect of client knowledge sources eco-innovation performance is positive. As Model 4 shows, the positive and significant coefficient of client sources ( $p < 0.001$ ) supports H1a. Likewise, for H1b, the positive coefficient of external supplier sources on eco-innovation performance is significant ( $p < 0.001$ ), supporting H1b (Model 3). H1c and H1d proposed that employing competitor and consultant knowledge sources positively affects eco-innovation performance. The data support H1c and H1d, as the regression coefficients for competitor and consultant sourcing were positive and significant ( $p < 0.001$  and  $p < 0.001$ ); Model 4 and Model 5, respectively)

We tested the interaction effects of client knowledge sourcing with the other three market knowledge source variables (Models 7 to 9). The interaction between client and supplier sourcing showed a positive and significant effect on eco-innovation performance ( $p < 0.05$ ), supporting H2a, which suggests that the simultaneous utilization of external information from clients and suppliers is complementary for eco-innovation purposes. We constructed an interaction plot for visual examination. Figure 1 shows that the effect of client knowledge sources is contingent on supplier knowledge sources. At low levels of supplier sourcing, increases in client use of information do not significantly change eco-innovation performance. However, when supplier sourcing is high, more utilization of client knowledge sourcing significantly increases eco-innovation performance. Hypothesis 2b proposed a complementary relationship between client and competitor knowledge sourcing on eco-innovation performance. The interaction coefficient is positive but not significant ( $p > 0.10$ ), rejecting H2b. Finally, H2c is partially supported ( $p < 0.10$ ), suggesting a positive interaction effect between client and consultant knowledge sourcing on eco-innovation performance. The interaction plot, shown in Figure 2, suggests that while client and consultant sources positively affect the performance of eco-innovations at the firm, they have a more pronounced impact on eco-innovation output when both types of external sourcing are high.





**Figure 1.** Interaction of client knowledge sources and supplier knowledge sources on eco-innovation performance.



**Figure 2.** Interaction of client knowledge sources and consultant knowledge sources on eco-innovation performance.

## 5. Discussion

This study began with the premise that the effects of specific market knowledge sources on eco-innovation performance have not been probed. Furthermore, we proposed that the effect of obtaining information from clients on the likelihood of eco-innovation is larger for organizations that also engage in inbound knowledge sources from other market stakeholders. The results show that all market knowledge sources, named clients, suppliers, competitors, and consultants, positively relate individually with eco-innovation performance. We also found that the combined effects of clients and suppliers, and clients and consultants, have a complementary effect on eco-innovation results. However, the joint use of clients and competitor external knowledge does not have a complementary relationship with eco-innovation. Below we discuss the implications of our study for theory and practice.

### 5.1. The Role of Market Sources in Eco-Innovation

Previous studies have found a positive relationship between open innovation activities and eco-innovation, but only at an aggregate level. For example, Horbach [27]

and Tariq et al. [26] found that critical drivers of eco-innovation performance are, among others, regulatory pressures, technological factors, and external knowledge sources. Our findings strengthen the theoretical bridge between open innovation and eco-innovation by proving a more fine-grained analysis of the role of particular market sources, which complements previous studies that established a more general picture of the determinants of eco-innovation. In particular, theorizing that focusing on inbound knowledge from clients, suppliers, competitors, and consultants acts as an enabler of eco-innovation performance and provides specific insights for firms where a primary goal is becoming a green or sustainable company.

Although evidence of complementarity between different external sources on innovation performance has been studied [28,77], our research adds further evidence about the positive joint effect of market knowledge sources on eco-innovation. We proved that firms that rely on information coming from their clients—essential for any business strategy—can be better utilized to boost eco-innovation performance when, at the same time, organizations use other external information coming from suppliers and consultant sources. These results are important to the study of the effect of open innovation on eco-innovation for two main reasons. First, our research contributes to better understanding what possible synergies between different external knowledge sources can occur when firms want to achieve effective eco-innovations. Second, our results suggest that it is crucial to know what combinations of external sources firms should utilize to create eco-innovations. Although previous literature has advanced on independent relationships between a group of drivers and eco-innovation performance [5,7,12], we found that some combinations of external sources can exhibit complementary effects (i.e., clients-suppliers and clients-consultants). In contrast, in the case of clients-competitors, we found no positive interaction for eco-innovation performance. Although we expected to find a positive interaction, much research will be needed to understand some contextual features (e.g., type of industry or state of development of a firm's country) that can influence collaboration with competitors. The new wave of sustainable business models is encouraging the development of more complex and collaborative relationships between different stakeholders (competitors included) [24,79]. Thus, our findings can provide an avenue to theorize, and then test, more complex combinations of knowledge sources aimed at driving open eco-innovation, as well as a more nuanced understanding of the conditions that can stimulate or hinder the synergy between knowledge sources.

Thus far, research of open innovation on eco-innovations has examined how different aggregate dimensions have practical effects on environmental innovations. Our study is a step forward to look into the effect of individual market categories and explore how each could enhance the introduction of eco-innovation with a positive effect on the firm's competitive advantage. An avenue for future research would be to extend this stream of research to other sources. For example, will specific institutional sources (governments, international agencies) and professional sources (research institutions, industry associations) affect eco-innovation performance differently? Similarly? And why? We also recommend more studies of the relative importance of different types of knowledge sources for sustainable innovations. Outcomes of such studies could help strategic managers pursue search activities that would be suitable to their firms' inbound open innovation strategy. In addition, our research explored the research question of what combination of market sources could complement each other in the development of eco-innovation performance. Future studies could expand this analysis, including other external sources not addressed in this study, along with internal knowledge sources, by asking: What combination of specific external and internal sources can best promote the introduction of effective eco-innovation?

Finally, our findings are also important for the literature of open innovation within the broader field of corporate sustainability, where collaboration between stakeholders has gained traction in recent years [80–82]. Our findings proved that collaborating with stakeholders is important to gather knowledge—from different market-based sources—that is beneficial for eco-innovation performance, which can also be translated to other types

of sustainability-driven innovation (e.g., positive-impact value creation) [3,83]. In addition, scholars have suggested that sustainability-driven collaboration should be grounded in processes of mutual learning that imply developing trusting and long-term relationships [47,55,84]. Therefore, our findings provide a basis to explore more complex open innovation strategies, where the combined effect of inbound and outbound open innovation approaches can be tested using multiple drivers of a sustainability-driven strategy (e.g., internal and external). In doing so, it will be important to explore how organizations can use open innovation as a catalyst for implementing multi-stakeholder partnerships [85], in order to strengthen the firm's capabilities to create social and environmental value [3,8,47].

### 5.2. Implications for Practice

From a practical standpoint, our study provides evidence-based knowledge for managers who seek to create eco-innovations that enhance the firm's competitive position. We proved that companies could strategically use different market sources to identify and create innovations to enhance a value proposition based on environmental or ecological attributes. In doing so, this study also has several implications for managers pursuing eco-innovation performance by applying an open innovation strategy. First, decision-makers should be aware of the importance of opening their minds to collaboration with both usual stakeholders, named suppliers and consultants, and other types of actors in the industry, such as their competitors. Based on our findings, we suggest that firms can benefit from engaging in co-opetition activities [86]—understood as the willingness to cooperate to create value while continuing competing to capture value—aimed at developing sustainable or green innovations. Second, our results suggest that managers should trust specific market sources across the firm's value chain if they want to find valuable knowledge that is not available within the company. Although the knowledge is not in the firm, managers are advised to seek input from collaborators and non-managers who have a more direct relationship with clients, suppliers, and consultants, in order to facilitate the connections needed to enable information flow from outside to inside the firm. Likewise, creating strong connections with competitors is necessary if managers want to be at the forefront of knowledge regarding the latest advances in processes and products that help to create environmental value. Third, considering the variety of market sources firms can utilize, managers should be aware that an open innovation strategy is not merely a decision to make, but also a process to manage. Effective management of the open innovation process could increase successful eco-innovations and reduce the time and financial resources employed. Overall, our results suggest that it is imperative to combine and integrate different market sources to maximize the flow of knowledge from outside the boundaries of the firm to create eco-innovative solutions for their clients.

## 6. Conclusions

This study contributes to the effort to bridge the literature on eco-innovation and open innovation by examining the effect of market knowledge sourcing on eco-innovation performance. First, our results suggest that an inbound open innovation strategy, which uses clients, suppliers, competitors, and consultants as knowledge sources, positively affects eco-innovation performance in organizations (i.e., a market-driven approach to eco-innovation). Second, we offer a more nuanced understanding of an inbound open eco-innovation strategy by exploring a complementary search approach. We found that a combination of client sourcing with supplier and consultant sources of knowledge positively affects eco-innovation performance, acting as complementary forces that drive successful eco-innovation. Together, our findings suggest that organizations can increase the likelihood of achieving successful eco-innovation if they consider the differences between particular open innovation sources and their combined influence. In so doing, firms can develop a more complex—and potentially more impactful—approach to eco-innovation, which is much needed today to offer solutions that can address the emergent need of environmental value creation.

Our study faces some limitations that should be taken into account in order to make sense of our findings. First, the Chilean Innovation Survey—similar to the Eurostat Community Innovation Survey that has been utilized in studies of open innovation in eco-innovation [87]—has several limitations, such as single firm response, the self-reported dependent variable and potential inaccuracy in survey answers. Thus, research related to the effect of open innovation processes on eco-innovation based on more fine-grained data could be more telling. Second, our sample includes solely Chilean firms, but our results (i.e., the influence of market knowledge sources on eco-innovation) are on a par with previous studies based on country samples from Europe [7,17]. Relatedly, due to changes in the questions asked in the Chilean Innovation Survey (including some of the independent variables that we used in our study) we could not utilize the last wave of data (2017), which forced us to cover only the period between 2009 and 2014. Although the findings regarding specific and combined market sources on eco-innovation performance are new to our knowledge, confirmation with more recent data from other countries is recommended. Third, we studied only a market knowledge sourcing strategy. Firms can also benefit from exploring the effect of professional and institutional knowledge sources to capture the relative influence of each of them, as well as the role that different employee groups can play in accessing this external knowledge (e.g., CEO, executive team, or R&D department). Hence, we recommend extending our findings by exploring individual and combined effects of different sourcing strategies on eco-innovation performance, and the role that different employee groups can perform in developing different sourcing strategies. Fourth, we did not theorize about the role of open innovation in specific eco-innovation dimensions (e.g., waste management, circular economy, green impact, sustainable packaging). Thus, future research comparing the relative role of market knowledge sources in specific eco-innovations can provide a deeper comprehension of this emergent innovation phenomenon. Finally, our dataset did not allow us to discern the nature of the sourcing strategy adopted by organizations (i.e., passive/reactive or active/proactive). We think the way in which organizations adopt open innovation strategies can have an interacting effect on eco-innovation performance. Thus, we recommend incorporating this variable in future theory building.

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