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A Taxonomy of Eco-Innovation Types in SMEs: Exploring Different Firm Profiles in the Canadian Wine Industry

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Abstract: The paper examines eco-innovation strategies in the Canadian wine industry. It uses firm-level data of 151 wine firms that developed eco-innovations between 2015 and 2017 to build a taxonomy of four eco-innovation strategies: (i) eco-innovation laggards, (ii) product-oriented eco-innovators, (iii) process-oriented eco-innovators, and (iv) fully integrated eco-innovators. We then characterize these eco-innovation strategies with respect to firm-level innovation capabilities, firms' knowledge openness, and firms' specific characteristics. The results reveal heterogeneity in eco-innovation strategies and show that these strategies exhibit different configurations of innovation-related conditions and firm characteristics.

Keywords: eco-innovation; taxonomy; wine industry; Canada

1. Introduction

In the last decade, the topic of eco-innovation has enjoyed growing popularity among the scholarly community [1–4]. A large number of studies have examined the determinants of eco-innovations to better understand the drivers that impact the adoption and development of eco-innovations by firms [5–11].

The eco-innovation literature lacks rich insights into firms' approaches to eco-innovation, however. Prior studies on the determinants of eco-innovations focus on distinct forms of eco-innovation [9,12]. This is problematic because it constrains the understanding of eco-innovation as a complex phenomenon, and in particular whether special relationships exist between different types of eco-innovation. Castellacci and Lie [13] and Kiefer et al. [14] argue that this issue deserves further research.

In the present paper, we investigate eco-innovation in a specific sector and in a specific context: the wine industry in Canada. The aim of this analysis is twofold. First, we attempt to classify firms adopting and developing eco-innovations into different groups (eco-innovation strategies). Second, we describe the characteristics of these eco-innovation strategies.

The study collected data from the Canadian wine industry, which is small by international standards. It produces about 0.3% of total world output [15], and its 604 wineries directly employ just over 5000 people [16]. Canada's wine industry is therefore unique and cannot easily be compared to other larger, more established and more traditional wine industries, whether in Europe, Australia or the USA. However, the recent growth of the industry [17], coupled with the development of new capabilities to address environmental issues and new growing practices, provides a natural experiment that allows the following questions to be explored. Can we identify distinct groups of wine firms on the basis of their eco-innovation profiles? Do these profiles differ with respect to innovation-related conditions and firms' structural characteristics?

This paper makes three contributions. First, it complements previous literature on the drivers of eco-innovations in the wine industry [18–21]. Second, it builds a new taxonomy that distinguishes between four eco-innovation profiles: (i) eco-innovation laggards, (ii) product-oriented eco-innovators, (iii) process-oriented eco-innovators, and (iv) fully integrated eco-innovators. Thus, this study ties into the view that approaches to eco-innovation within the wine industry cannot be treated as homogeneous and may vary across firms within the same sector. Third, it provides new firm-level evidence for the case of wine industry in Canada, which is unique in that it is taking full advantage of the changing climate, but which therefore also faces a number of environmental issues that influence the adoption and development of new environmental practices.

The structure of the paper is organized as follows. Section 2 discusses the theoretical background. Section 3 presents the research methods, including the data-collection measures and analytical procedures employed. Section 4 discusses the results. Finally, Section 5 concludes by discussing the results and their implications for the management of eco-innovation and future research.

2. Literature Review

2.1. Definitions of Eco-Innovation

This study adheres to the three components of eco-innovation conceptualized by Rennings' seminal work [22] (p. 322), according to which eco-innovation is an “innovation process [geared] toward sustainable development”; relies on the introduction or application of “new ideas, patterns of behaviours, products and processes”; and attempts to “contribute to a reduction of environmental burdens or to ecologically specified sustainability targets”.

Eco-innovation is based on the recognition of the value of sustainability. “Sustainability” refers to an organization's ability to create value to the benefit of the environment. It requires not only proficiency in decreasing environment impacts, but also, and more importantly, the ability to value activities and processes that are more sustainable. This is echoed by Costantini et al. [23] (p. 865), who argue that eco-innovation is “an innovation that brings about a reduction of the environmental impacts of production and consumption activities”.

The second component of the definition of eco-innovation involves an organization's ability to acquire and process knowledge, and to adopt and develop new processes and/or products, services and organizational practices that value the environment.

Finally, the third component of Renning's definition refers to the outcomes and results of the new capabilities developed by an organization. As stressed by Kemp and Pearson [24] (p. 7) eco-innovation can be defined as “the production, assimilation, or exploitation of a product, production process, service, or management method that is novel to the organisation (developing or adopting it) and which results, throughout its lifecycle, in a reduction of environmental risk, pollution, and other negative impacts of resources used (including energy use) compared to relevant alternatives”.

On the whole, these definitions of eco-innovation identify innovations that are developed and adopted in relation to the environment. In the words of Jesus Pachebo et al. [25] (p. 46), “Eco-innovations consist in changes to the environmental performance and improvements based on the dynamics of ecologizing products, processes, business strategies, markets, technologies, and systems of innovation”.

Although there is no single agreed-upon definition of eco-innovation, what is common to all of them is that eco-innovations and related practices involve the creation of new products, services, and processes that contribute to sustainable development, are designed to be more resource-efficient, and have a reduced environmental impact.

2.2. Drivers or Determinants of (Eco) Innovation

What factors encourage firms to adopt and develop eco-innovations? It has been argued that eco-innovation results from the ability to locate, identify, value, and acquire new knowledge relevant to a firm [26]. This article therefore builds on the knowledge-based view of firms to recognize the value

of knowledge assets [27,28] that encourage firms to adopt eco-innovations. We also refer to the open innovation literature [29,30], which explains the relevance of exploiting a variety of knowledge sources within and beyond firms' boundaries.

Studies on eco-innovation provide ample evidence regarding the drivers of eco-innovations [2–4,6,7,9–11]. As Muscio et al. [20] have stressed, however, little is known about the role of firms' internal capabilities and organization characteristics in driving eco-innovation. Moreover, Cuerva et al. [31] point to the need to study in more depth the relationship between firm-specific characteristics and eco-innovation drivers.

First, firms' recognition, assimilation and exploitation of new knowledge is largely a function of their absorptive capacity, which is related to their ability to innovate and capacity to identify valuable knowledge from outside the firm [32]. According to Lee and Min [33] (p. 535), eco-innovation R&D contributes to the continuous improvement of internal resources and capabilities to achieve superior environmental performance. However, prior research on eco-innovations has not reached a consensus on whether internal R&D is a crucial determinant of successful eco-innovation. For example, Cainelli et al. [34] have found that internal R&D is positively related to environmental innovation by increasing internal innovation resources, while Horbach [35] and Cuerva et al. [31] have found that internal R&D is not directly related to eco-innovation, and De Marchi [36] has found no support for the view that the intensity of R&D has an effect on eco-innovations.

Second, the use of external knowledge by firms is critical for eco-innovation outcomes. The open innovation research recognizes that a firm's openness to external knowledge sources and collaboration increases firms' knowledge base [29,30]. The argument advanced in the literature is that innovation is strongly linked to firms' ability to capture and use a wide range of knowledge from other firms and organizations. A recent systematic review of the empirical literature [37] on the impact of the use of external knowledge sources shows that knowledge can reside in users and suppliers, competing firms, service firms, and organizations outside the industrial system. Studies that explore the relationship between open search strategies and collaboration, on the one hand, and eco-innovation, on the other, yield mixed results. Some studies show that external cooperation and external sources of knowledge are important in enabling eco-innovation [20,36]. Horbach [35] shows that the use of external knowledge has a significant effect for only certain types of eco-innovations. Triguero et al. [10] have found that universities and public research institutions are the main contributors to improving firms' eco-innovation performance.

Third, adopting and developing eco-innovations can be contingent on firms' structural characteristics. Castellacci and Lie [13] and Bossle et al. [4] point out that firm size has a significant effect in this regard, whereas Pinget et al. [38] show that older firms are more likely to develop and adopt eco-innovations because they possess more competences, knowledge and resources to support an environmental innovation strategy. A similar conclusion is reached by Protogerou et al. [39], who show that young and small firms can suffer from the liability of newness, and that small firms have limited innovation opportunities and limited knowledge resources. Cassiman et al. [40] explain that there is a positive relationship between exports and innovation, whereas Pinget et al. [38] show that internationalized firms are more likely to develop environmental strategies. Asheim et al. [41] reveal that innovation can be impacted by firms' location because regions differ in terms of their institutional and economic composition, knowledge concentration, and network density, among other factors.

2.3. Research Issues and Questions

Our starting point is the consideration that different forms of eco-innovation can be linked to each other. As explained by Castellacci and Lie [13] (p. 1039), "firms which invest in green technologies do not focus on only one type of eco-innovation, but they simultaneously invest to produce different types of green innovations". Castellacci and Lie [13] also argue that there is a general degree of association between different types of eco-innovation, and this paper examines this claim in the context of the wine industry, where the importance of eco-innovations has been increasing in recent years [20]. On the basis of these considerations, and in the context of the Canadian wine industry, it can be expected that

when firms are involved in eco-innovations, they tend to produce more than one type of eco-innovation simultaneously. Therefore, the first research question addressed in this study is concerned with the extent to which different types of eco-innovation are linked to each other.

Research Question 1: Can we identify distinct groups of wine firms on the basis of their configurations (or patterns) of eco-innovation?

The second research question investigates the set of drivers or determinants of eco-innovations. As Del Rio et al. [6] have argued, the relevance of different determinants of eco-innovation for eco-innovators and eco-innovation types has not been studied sufficiently. Depending on the industry's characteristics, a firm's capacity to develop and adopt eco-innovations is influenced by different conditions, including environment, market, technology, and policies [4,7,10]. Based on these considerations, it can be expected that different eco-innovation strategies will exhibit different configurations of innovation-related factors and firm characteristics. Therefore, our second research question is concerned with identifying eco-innovation factors in the context of the wine industry.

Research Question 2: Do these profiles differ with respect to innovation-related conditions and firms' structural characteristics?

3. Research Design and Methodology

3.1. Questionnaire and Data Collection

To test our ideas, our empirical analysis was based upon a survey of 151 Canadian winemakers conducted in the summer of 2018. These 151 winemakers were sampled from the 522 winemakers that we identified by referring to provincial winemaker registries. This represents an effective participation rate of 28.9%. Many academic articles using original firm-level surveys with similar participation rates have now been published [21,41]. Data collection was conducted by a third-party survey firm using computer assisted telephone surveying.

The core questions in the questionnaire were based on a comprehensive review of the literature on the wine industry, the OECD's Oslo Manual and the Canadian Survey on Innovation and Business Strategy. It included questions about innovation activities and innovation types and the importance of different sources of knowledge for firms' innovation activities. The survey also collected information on firms' environmental practices. Data regarding such activities can be found in the Canadian Survey on Innovation and Business Strategy and in various national innovation surveys.

For this paper, the main question was related to different innovations with environmental benefits. Similarly to the Canadian Survey on Innovation and Business Strategy, we asked the following question: *During the three years from 2015 to 2017, did your firm introduce an innovation with any of the following environmental benefits?* First, there are five types of eco-innovation with benefits stemming from resource efficiency.

- Reduced materials use per unit of output (Env_1).
- Reduced energy use per unit of output (Env_2).
- Replacing materials with less greenhouse gas intensive alternatives (Env_3).
- Reduced consumption of resources through recycling (Env_4).
- Renewable fuels: ethanol, biodiesel, biogas, biochar, hydrogen (Env_5).

Second, there are two types of eco-innovation with benefits for environmental-protection activities.

- Reduced air, water, soil or noise pollution (Env_6).
- Reduced greenhouse gas emissions (Env_7).

Third, there are three types of eco-innovation with benefits to the end user and/or consumer.

- Reduced energy use or increased energy efficiency for the consumer or end user (Env_8).

- Reduced air, water, soil, or noise pollution for the consumer or end user (Env_9).
- Reduced greenhouse gas emissions for the consumer or end user (Env_10).

Each of these eco-innovations was operationalized as a dummy that took the value of 1 if the firm introduced the eco-innovation during the 2015–2017 period, and 0 otherwise.

3.2. Analytical Procedure

The objective of the empirical analysis was to search for a taxonomy of eco-innovation strategies in the Canadian wine sector and relate each strategy to a set of innovation-related conditions and firms' structural factors. The method chosen to develop this taxonomy was characterized as follows: (a) it was based on an analysis of firm-level data; it was therefore not assumed that firms in the wine industry are homogeneous in terms of their eco-innovation strategies; instead, we explicitly investigated whether there were different patterns of eco-innovation in the wine industry; (b) we used formal statistical procedures to identify eco-innovation strategies similar to those used by Castellacci and Lie [13] and Kiefer et al. [14], who developed a taxonomy of the combinations of the different forms of eco-innovation produced by firms; (c) the data we used were better suited for investigating small firms (fewer than 20 employees) than the Canadian Survey on Innovation and Business Strategy, and there is a lack of official statistics on the Canadian wine industry.

To determine eco-innovation strategies, we first conducted a principal component analysis, followed by a cluster analysis. The principal component analysis was performed on the set of ten eco-innovation variables listed in Table 1. This procedure made it possible to extract a series of orthogonal components that combined variables that were highly correlated to one another. This step intended to reveal that some eco-innovation types are closely related to each other, and that the ten eco-innovation variables can therefore be grouped into a small number of eco-innovation dimensions. The value of Kaiser–Meyer–Olkin (KMO) was 0.831, which is above the accepted minimum of 0.600, and Bartlett's sphericity tests also supported the validity of the test. Finally, we performed an orthogonal varimax rotation technique to identify factors with eigenvalues greater than 1. These factors were composite variables that combined the ten eco-innovations that were highly correlated at the firm level.

Second, we conducted a cluster analysis on these factors, the objective of which was to identify the number of clusters, i.e., groups of homogeneous wine firms with similar eco-innovation profiles (these profiles are described in Section 4.3). In order to identify the number of clusters, we adopted a two-step approach. First, we performed a hierarchical cluster with Ward's method based on squared Euclidian distances. Second, we considered a set of initial solutions of three and four clusters based on the agglomeration schedule. Then we performed nonhierarchical cluster analyses to determine the final solution. Using the K-means cluster analysis, we generated solutions with three- and four-group solutions. After comparing the two cluster solutions, we decided to choose the four-cluster solution for two reasons: (1) this solution provides greater conceptual value in terms of eco-innovation strategies; and (2) there was a sufficient number of firms in each cluster to analyse differences among groups for all the different activities associated with eco-innovations. An ANOVA test was performed and the differences in means were found across all clusters in the four-cluster solution.

Third, we used descriptive statistics to relate each eco-innovation strategy to the set of determinants associated with it. The choice of the explanatory variables followed from previous works on the determinants of eco-innovations (see Section 2.2) and was also restricted by the variables available in our dataset (the questionnaire was primarily focused on innovation and did not include questions about regulations regarding the introduction of eco-innovations. Apart from the special modules on eco-innovations, the questionnaire also inquired into firms' characteristics and their general innovation activities). We included three sets of determinants in the analysis. The first was related to firm-characteristic variables. *Small firm* referred to firms that have fewer than ten employees, *young firm* captured firms less than ten years old, *exporter* referred to firms that declared having sales outside Canada, and *location* referred to the geographical location of the firms. Three regional dummies were created: *British Columbia*, *Quebec*, and *Ontario*. The second set of drivers related to

firms' innovation capacity. The examination of the capability dimension was based on two variables related to R&D activity (*internal R&D* and *external R&D*), and one variable relates to *cooperation*—that is, active participation with other enterprises or institutions on innovation activities. The third set of determinants was related to the importance of the sources of knowledge used by firms in their innovation activities. The importance of eight different knowledge sources was analysed independently.

4. Results

4.1. Basic characteristics

Tables 1 and 2 present descriptive statistics regarding the types of eco-innovation and the determinants of eco-innovations.

As can be seen in Table 1, the distribution of firms with regard to different types of eco-innovations is as follows: over the 2015–2017 period, 62.3% of the sample indicated that they developed or improved resource efficiency by recycling water, waste, or materials (Env_4); 57.0% indicated that they developed or improved energy use (Env_8) and materials use for the consumer (Env_9); 55.6% indicated they developed or improved resource efficiency through reduced materials use per unit of output (Env_1); and 49.0% indicated that they developed or improved environmental-protection activities by reducing air, water, soil, or air pollution (Env_6). As for the other forms of eco-innovation, the descriptive analysis of the data revealed that the percentage of firms that had developed or improved such forms of eco-innovation were lower, ranging from 42.4% (Env_2) to 13.9% of the sample (Env_5).

The descriptive statistics of the explanatory variables used in this study are reported in Table 2. With regard to firm-specific characteristics, 49.0% of the firms had less than 10 employees, 36.4% were young, and about 25.5% declared export activities. Regarding the location of the firms, 28.5% were located in British Columbia, 42.4% in Quebec, and 29.1% in Ontario. With regard to innovation activities, 55.6% of the firms conducted internal R&D on a regular basis, 23.2% conducted external R&D, and about 41.7% were involved in at least one collaboration. With regard to knowledge sources, winemakers and clients were the two most important knowledge sources used by firms in their innovation activities, followed by suppliers. Of least importance were knowledge sources from competitors, knowledge-generating organizations, and industrial associations.

Table 1. Statistics about eco-innovations.

Variable	Description	Mean	Std. Dev	Min	Max
ENV_1	Reducing materials use per unit of output	0.556	0.498	0	1
ENV_2	Reducing energy use per unit of output	0.424	0.496	0	1
ENV_3	Replacing materials with less polluting	0.311	0.465	0	1
ENV_4	Recycling water, waste or materials	0.623	0.486	0	1
ENV_5	Renewing fuels	0.139	0.347	0	1
ENV_6	Reducing air, water, soil or air pollution	0.490	0.502	0	1
ENV_7	Reducing greenhouse gas emissions	0.298	0.459	0	1
ENV_8	Reducing energy use for the consumer	0.570	0.497	0	1
ENV_9	Reducing materials use or increasing recycling for the consumer	0.570	0.497	0	1
ENV_10	Reducing greenhouse gas emissions for the consumer	0.245	0.432	0	1

Table 2. Descriptive statistics.

Variables	Description	Mean	Std. Dev
Firm-specific characteristics			
Small firm	1 = Firm with less than 10 employees	0.490	0.502
Young firm	1 = Firm with less than 10 years	0.364	0.482
Exporter	1 = Firm with sales on foreign market in 2017	0.258	0.439
Location	1 = Firm located in British Columbia	0.285	0.459
	1 = Firm located in Quebec	0.424	0.496
	1 = Firm located in Ontario	0.291	0.456
Innovation activities			
Internal R&D	1 = Firm with intramural R&D	0.556	0.498
External R&D	1 = Firm with extramural R&D	0.232	0.423
Cooperation	1 = Firm is involved in at least one cooperation	0.417	0.495
Knowledge sources			
Winemaker	1 = High importance of winemaker as sources of innovation	0.808	0.395
Clients	1 = High importance of clients as sources of innovation	0.669	0.472
Suppliers	1 = High importance of suppliers as sources of innovation	0.291	0.456
Competitors	1 = High importance of competitors as sources of innovation	0.179	0.384
KIBS	1 = High importance of KIBS as sources of innovation	0.219	0.415
HEIs	1 = High importance of HEIs as sources of innovation	0.119	0.325
Research institute	1 = High importance of research institutes as sources of innovation	0.166	0.373
Industrial association	1 = High importance of industrial association as source of innovation	0.245	0.432

4.2. Eco-Innovation Factors

The principal component analysis synthesized a number of variables that account for the observed factor loading shown in Table 3. Three factors with eigenvalues greater than 1 were extracted and account for 61.7% of the total variance. The first principal component factor accounts for a high loading on the three variables measuring environmental practices related to benefits to the end user and/or consumer (ENV_8, ENV_9 and ENV_10) with firms that reported replacing materials with less polluting alternatives (ENV_3) and reducing greenhouse gas emission (ENV_7). This Factor 1 is labelled *end user eco-innovators*. The second principal component combined three eco-innovation variables related to the efficient use of resources (ENV_1, ENV_2 and ENV_4) with variables related to reducing air, water, soil, or air pollution (ENV_6). This Factor 2 is labelled *efficient use of resources*. The third principal factor component had a very high loading on the indicator that measures renewable fuels (ENV_5). This variable does not correlate with other variables. This Factor 3 is labelled *renewable fuels innovators*.

A number of features emerged from this analysis. The principal one is that many wine firms that report eco-innovations related to the end user also engage in eco-innovations related to increasing both the efficient use of resources and environmental-protection activities (Factor 1). As well, firms that introduce eco-innovations related to the efficient use of resources also introduce eco-innovations that increase environmental-protection activities (Factor 2). Finally, there are eco-innovations that are not strongly correlated with other forms of eco-innovation (Factor 3).

Table 3. Results of factor analysis: Factor loadings.

	Factor 1: End user	Factor 2: Efficient use of resources	Factor 3: Renewable fuels
ENV_1	0.024	0.876	0.106
ENV_2	0.234	0.659	0.184
ENV_3	0.621	0.285	0.321
ENV_4	0.398	0.494	0.029
ENV_5	0.175	0.191	0.855
ENV_6	0.428	0.460	0.319
ENV_7	0.834	0.125	0.193
ENV_8	0.692	0.296	−0.023
ENV_9	0.523	0.306	−0.397
ENV_10	0.771	0.086	0.078
% of variance	41.2	10.5	10.0

4.3. Eco-Innovation Clusters

As noted in the previous section, the next step in the empirical approach was to use these three principal components as input variables in a cluster analysis. The results of the cluster analysis are reported in Table 4.

The first cluster includes 36 firms (23.8% of total firms) that showed relatively low coefficients in all factors except one: renewable fuels innovations (for which it ranks second highest). This cluster is relatively weak in two eco-innovation dimensions: product-oriented and process-oriented eco-innovations. This cluster is therefore called *eco-innovation laggards*. The second cluster, comprising 32 firms (21.2% of total firms), has above-average values on the first principal component, and it identifies a group of firms that have introduced product innovations that reduce energy, materials, and greenhouse gas emissions for the customer. This cluster is labelled *product-oriented eco-innovators*. The third cluster is by far the largest (31.1% of total firms) and has a very high mean value for firms that have introduced process eco-innovations that reduce materials and energy and recycle. This cluster is named *process-oriented eco-innovators*. Finally, the fourth cluster (23.8% of total firms) differs from the others in that it has a high mean value for the second and third principal components and an above-average value for the first, thus identifying firms that innovate along a different eco-innovation trajectory (renewable fuels, process, and end user). This cluster is therefore called *fully integrated eco-innovators*.

Table 4. Cluster analysis (mean values of principal components in each cluster).

Factor	Clusters				F-value
	1	2	3	4	
Factor 1: End user	−0.73821	1.40880	−0.51253	0.15507	87.9 ***
Factor 2: Efficient use of resources	−1.26687	−0.28474	0.76921	0.51572	91.7 ***
Factor 3: Renewable fuels	0.00828	−0.43807	−0.77741	1.39567	113.1 ***
N =	36	32	47	36	

*** $p < 0.001$.

4.4. The Determinants of Eco-Innovation

In this section, we characterize the four eco-innovation strategies using the variables listed in Table 2, which refers to the structural characteristics of the firms, innovation-related activities, and knowledge sources. Table 5 shows the mean of these variables for each of the four clusters, as well as for the wine sector as a whole.

First, the four eco-innovation strategies correspond to different types of firms, especially with regard to firm-level characteristics. Firms in Cluster 1 tended to be younger, whereas firms in Clusters

2 and 3 tended to be larger (more than ten employees). The share of firms in Clusters 3 and 4 that exported their products to foreign markets was higher than in other clusters. The distribution of the firms in the three regions over the four clusters differs significantly, suggesting that there is a tendency for certain eco-innovation strategies to better reflect firms in some wine regions than in others. In British Columbia, there is a greater concentration of firms in Cluster 1 (*eco-innovation laggards*), whereas Ontario has an overrepresentation of firms in Clusters 1 and 4 (*fully integrated eco-innovators*) and an underrepresentation of firms in Cluster 3 (*process-oriented eco-innovators*). In contrast, Quebec, with a concentration of firms in Clusters 3 and 4, encourages both product- and process-oriented eco-innovations. These results reveal the peculiarities of the geography of eco-innovation in the Canadian wine industry. There is some evidence that specific eco-innovation strategies are more likely in specific regions, although all strategies are represented in each of the three wine regions. Further investigation from a geographical perspective is required in order to examine whether this result is due to some difference in regional policies, incentives, or regulations among these regions, or is related to other contextual factors.

Second, regarding the innovation activities wine firms exploit to achieve eco-innovation, there is an important difference between Clusters 1 and 2, on the one hand, and Clusters 3 and 4, on the other. Firms in the first two clusters attach less importance to cooperation with external actors in their eco-innovation activities. However, Clusters 1 and 2 differ from each other in two important respects. First, firms in Cluster 2 attach far greater importance to external R&D than firms in the other clusters. Second, internal R&D activity is of little relevance for firms in Cluster 1, while it is a far more important determinant of eco-innovations in the other three clusters. Most firms in Clusters 3 and 4 are characterized by stronger internal R&D capabilities and more frequent cooperation with external actors, but weaker external R&D than firms in Cluster 2.

Third, the type of external information sources considered important varies across eco-innovation strategies. Firms in Cluster 4 appear to be more extroverted, attaching far greater importance to external sources, both market and institutional, and considering them important sources of knowledge for their innovation activities. Firms in Cluster 3 are more introverted, attaching far greater importance to internal sources of information (the winemaker) and less to external sources of information. Firms in Cluster 1 assign the highest importance to suppliers, whereas firms in Cluster 2 assign the highest importance to the winemaker and competitors. The breadth (or variety) of knowledge sources also varies significantly across eco-innovation strategies: in particular, *process-oriented eco-innovators* (Cluster 3) tend to have a low breadth of knowledge sources, assigning high importance to knowledge from winemakers, whereas *fully integrated eco-innovators* (Cluster 4) tend to have a high breadth of knowledge sources used. *Eco-innovation laggards* (Cluster 1) and *product-oriented eco-innovators* (Cluster 2) have a low breadth of knowledge sources used.

Table 5. Values of driver variables for each cluster.

	Cluster				Total
	1	2	3	4	
Firm characteristics					
Young firm	47.2	31.3	36.2	30.6	36.4
Small firm	38.9	56.3	48.9	52.8	49.0
Exporter	25.0	18.8	27.7	30.6	25.8
<i>Location</i>					
British Columbia	38.9	25.0	23.4	27.8	28.5
Quebec	25.0	46.9	59.6	33.3	42.4
Ontario	36.1	28.1	17.0	38.9	29.1
Innovation activities					
Internal R&D	25.0	56.3	66.0	72.2	55.6
External R&D	22.2	31.3	23.4	16.7	23.2
Cooperation	33.0	37.5	34.7	50.0	41.7
Knowledge sources					
Winemaker	72.2	87.5	83.0	80.6	80.8
Clients	63.9	68.8	63.8	72.2	66.9
Suppliers	36.1	25.0	25.5	30.6	29.1
Competitors	11.1	25.0	14.9	22.2	17.9
Higher-education institution (HEIs)	5.6	18.8	6.4	19.4	11.9
Research institute	16.6	15.6	12.8	22.2	16.6
Industrial association	25.0	15.6	23.4	33.3	24.5
N=	36	32	47	36	151
(%)	100	100	100	100	100

4.5. Discussion

Table 6 summarizes the characteristics of each of the four clusters and presents the factors that distinguish each group of firms.

Cluster 1, *eco-innovation laggards*, comprises firms in which (process) eco-innovations appear to be quite marginal. This is not surprising in view of the unfavourable factors determining innovation activity: weak R&D activity and cooperation and relatively poor use of and interaction with external knowledge, with the exception of suppliers and industry associations. This cluster includes firms across the different wine-producing regions, but with a high concentration in British Columbia and Ontario. These firms typically have a weak capacity to innovate, and they are mostly young and produce wines for the domestic market only.

Cluster 2, *product-oriented eco-innovators*, engages in innovation through technological changes that yield environmental improvements related to benefits for the end user and consumer. Many firms in this cluster regard reductions in energy use, pollution, and greenhouse gas emissions important objectives of innovation. Firms in this cluster are mostly small, and their eco-innovation activities strongly benefit from external R&D and a relatively wide network that spans the entire value chain (clients and competitors), with strong links to higher-education institutions (HEIs). This cluster has a high proportion of (very) small firms, mostly located in Quebec, that sell their products in the domestic market.

Cluster 3, *process-oriented eco-innovators*, pursues environmental practices aimed at improving resource efficiency by reducing materials and energy use or by recycling. In general, networking and the use of external knowledge sources are rather weak. These firms' own innovation activities strongly benefit from the development of internal R&D capabilities and know-how from internal winemakers. This cluster consists of a high proportion of firms in Quebec with an above-average export orientation. It is important to note that Cluster 3 is the largest. The large size of the cluster indicates that many wine firms regard environmental practices related to the efficient use of resources an important objective of their eco-innovation strategy.

Finally, Cluster 4, *fully integrated eco-innovators*, engages in different eco-innovation trajectories, coupling product- and process-oriented eco-innovations. Firms in this cluster have the most favourable conditions determining eco-innovation. This cluster has a high level of innovation activities that support technological activities in R&D and a favourable environment in terms of innovation opportunities and market perspectives. Internal R&D is supported by an intensive use of market- and science-related external knowledge sources, as well as many cooperation agreements with external partners.

Table 6. Summary of characteristics of eco-innovation strategies in the Canadian wine industry.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Firm characteristics	Young firms, British Columbia, Ontario	Small firms, Quebec	High export propensity, Quebec	Small firms, high export propensity, Ontario
Innovation activities	Technological ladders	External R&D	Internal R&D, cooperation	Internal R&D, cooperation
Knowledge sources	Suppliers, industry association	Winemaker, clients, competitors, HEIs	Internal, winemaker	Clients, suppliers, competitors, HEIs, research institutes, industry association

5. Concluding Remarks and Implications

We applied a cluster analysis to a large set of eco-innovation indicators to identify four eco-innovation strategies characterized by three groups of variables: (a) structural characteristics of the firms, (b) innovation activities, and (c) knowledge sources. In view of the distinct patterns exhibited by these variables, we identified four clusters: (1) eco-innovation ladders, (2) product-oriented eco-innovators, (3) process-oriented eco-innovators, and (4) fully integrated eco-innovators.

Consistent with the literature [1,10,13], certain key observations can be made about these clusters. First, there is a heterogeneity of firms with respect to their eco-innovation strategies. Moreover, each strategy involves a combination of eco-innovation activities. A large number (*eco-innovation ladders*) have very low levels of eco-innovation activity; however, these low levels are averages, and even within this group certain firms no doubt engage in eco-innovation. Some firms (*product-oriented eco-innovators* and *process-oriented eco-innovators*) tend to rely strongly on one specific form of eco-innovation. Among them, there is a distinction between firms that develop eco-innovations that benefit from production that uses resources efficiently (*process-oriented eco-innovators*) and those that provide benefits to end users (*product-oriented eco-innovators*). Finally, there are firms that develop different combinations of eco-innovations (*fully integrated eco-innovators*).

The findings reveal that different innovation activities and knowledge sources affect eco-innovation differently. The activities among firms that adopt a passive eco-innovation strategy (*eco-innovation ladders*) substantially differ from those of firms more actively engaged in eco-innovations. R&D, cooperation, and the use of several market- and scientific-related knowledge sources have a strong effect on the most successful eco-innovation strategy (*fully integrated eco-innovators*). Internalized innovation activities, including in-house R&D and the use of the winemaker characterize firms that are more *process-oriented eco-innovators*, whereas *product-oriented eco-innovators* value more external R&D and knowledge from the winemaker, but also from markets and university sources.

Overall, these findings have important implications for policymakers. In Canada, policymakers are creating new programmes to encourage the adoption and development of new environmental practices. Therefore, it is important to understand different types of eco-innovation and their main drivers. We maintain that policies must not expect homogenous firms when targeting the wine industry, but instead address them according to the forms of eco-innovation in which they engage. This heterogeneity calls for incentives that consider the multidimensional nature of eco-innovation and avoid a narrow understanding of eco-innovation. The findings also indicate that wine firms, at least in the context of Canada, combine different forms of eco-innovation simultaneously. It clearly follows that policies need to be informed about these combinations, which can be highly idiosyncratic at the

firm level. This suggests that policies must focus on the distinctive characteristics of firms in designing eco-innovation policy incentives. Policies thus need to consider the heterogeneity of eco-innovation strategies and the potential synergies of combinative eco-innovation trajectories.

There are a few limitations to this study, and some of them offer promising avenues for future research. The first is that this study is limited to only eco-innovations introduced over a three-year period. Wine firms in the process of developing eco-innovations were not identified. Such firms are beyond the scope of the present study, but they raise an interesting question for future research: is there significant variability in the patterns observed among firms that are in the process of implementing eco-innovations? Second, in this study we used a set of determinants of innovation that was restricted by the variables available in our dataset, which implies that we may have missed other determinants of eco-innovation, such as policies, incentives, or regulations. Further studies might want to consider these and other eco-innovation variables. The third limitation is inherent to the cross-sectional data, which provides a useful snapshot of eco-innovation among wine firms in Canada at a specific time. Further studies might want to investigate how eco-innovation strategies evolve and change over time or the effects of such changes on firms' activities and strategies. Finally, this study examines the wine industry in Canada and adds to our understanding of eco-innovations in a new context. It reveals that wine firms adopt different eco-innovation strategies, and that these strategies are distinguished by specific innovation-related activities and firm-level characteristics. Therefore, it is necessary to replicate this study in other wine regions and countries to ensure the validity and generalizability of the study's findings.

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