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Environmental management capabilities for a ‘circular eco-innovation’

Dynamic capabilities for the loops closing.

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1. Introduction

Eco-innovation is key to transforming the traditional linear system of production and consumption into a circular economy (CE). The CE is a model promoted by governments and institutions that requires radical and systemic eco-innovation to transform linear patterns into circular flows of raw materials (EOI, 2016). The CE focuses on achieving a closed-loop material and balanced-energy economy through the application of the principle of the '3Rs' (reducing, reusing, and recycling). Re-manufacturing is considered an effective way of fostering closed-loop materials processes (Inigo & Blok, 2019; Zhang, Chu, Wang, Liu, & Cui, 2011). Its key premise is that waste minimisation can serve as a new source of business value (Perey, Benn, Agarwal, & Edwards, 2018).

We may consider the CE as a form of environmental management operating on several levels: at the national or regional (i.e. macro level), the goal is to decouple economic growth from consumption; at the eco-industrial park level (meso level), the goal is to promote regional development and the natural environment (Scarpellini, Portillo-Tarragona, Aranda-Usón, & Llena-Macarulla, 2019); at the micro level (or individual firm level), the goal is to find cleaner production approaches to achieve a more efficient use of raw materials and resources (Ghisellini, Cialani, & Ulgiati, 2016; Mathews & Tan, 2011; Murray, Skene, & Haynes, 2017).

A CE requires new production and consumption patterns as well as new innovations (Banaite & Tamosiuniene, 2016). New innovative concepts, technologies, and actors must be developed to address the complexity of current sustainability problems and thus achieve a CE (Ghisellini et al., 2016). This is the crux of the importance of eco-innovation and the need to measure it as part of CE implementation (Prieto-Sandoval, Jaca, & Ormazabal, 2018). Systemic eco-innovation is the key to the CE paradigm shift because it goes beyond single technologies and comprises clusters emerging in different areas (de Jesus, Antunes, Santos, & Mendonça, 2018).

Business eco-innovation and the CE are interrelated subjects of analysis because eco-innovation implies a positive environmental impact that can be applied to the circular business model. However, little is known about how eco-innovation can facilitate the change to a CE (de Jesus et al., 2018), particularly at a micro level. Some authors assert that eco-innovation contributes to the CE in a variety of ways because it is likely driven by diverse factors (Del Río, Romero-Jordán, & Peñasco, 2017).

At a micro level, the CE will require the expansion of new business models that are already emerging in different areas, from product–service systems for rental and the continuous-upgrade model of the sharing economy with the active participation of so-called 'prosumers' (European Commission, 2015) to 'cradle to cradle', the complete lifecycle model, and industrial symbiosis (Daddi, Nucci, & Iraldo, 2017; Genovese, Acquaye, Figueroa, Koh, & Lenny Koh, 2017). Thus, we can assume a priori that firms apply common procedures, routines, and capabilities to both processes and activities for eco-innovation and the CE. In other words, firms that have previously demonstrated capabilities related to eco-innovation and that can apply them to new innovative circular models could implement CE-related activities more easily. Precisely how environmental capabilities applied to eco-innovative processes could be redefined and repurposed for a circular business model is a novel line of inquiry calling for a micro-level analysis of the CE.

The capabilities applied to eco-innovation have been widely analysed from the resource-based view (RBV) and dynamic capabilities perspective due to their influence on internal eco-innovative processes (Portillo-Tarragona, Scarpellini, Moneva, Valero-Gil, & Aranda-Usón, 2018; Walton, Zhang, & O'Kane, 2019). However, research focused on the micro level, particularly on firms' specific capabilities and their CE involvement, remains scant (Aranda-Usón, Portillo-Tarragona, Marín-Vinuesa, & Scarpellini, 2019; de Jesus et al., 2018; Katz Gerro & López Sintas, 2019). In a CE-related study, Garcés-Ayerbe et al. (2019) called for a theoretical framework in the environmental management literature, and Kabongo and Boiral (2017) considered dynamic capabilities as part of a theoretical framework for analysing eco-efficiency processes in firms. However, few studies have analysed the previous business routines and activities that could facilitate the introduction of a CE (Perey et al., 2018; Stewart & Niero, 2018). This study seeks to fill that gap.

From a CE perspective, firms' existing resources and capabilities are required to facilitate the introduction of organisational changes and the development of competences in a dynamic environment. (Katz Gerro & López Sintas, 2019) state that environmental management systems (EMSs) can transform knowledge into capabilities and routines by changing the organisation. Eco-innovative processes can facilitate the implementation of the new organisational routines that are required to introduce CE-related activities and thus circular eco-innovation (Demirel & Danisman, 2019), which will then produce eco-innovative products and processes that can close material loops.

The analysis of formal and informal EMSs applied to eco-innovation and to the CE at the micro level is a novel research area. This study's main objective is to define and measure within a broad framework the common environmental capabilities applied by business to both eco-innovation and the CE to support environmental management and decision making. Specifically, this study analyses the 'circular eco-innovation 'through a model of the cause-and-effect relationship between firms' eco-innovation, circular practices and formal and informal EMSs using partial least squares structural equation modeling (PLS-SEM) and tests it on a sample of Spanish companies.

The remainder of this paper is structured as follows. The next two sections review the literature and describe the study's methodology. Then, the results are summarised and discussed within the dynamic capabilities framework. Finally, the study's main findings and conclusions are outlined.

2. Background

2.1 The intersection of eco-innovation and the circular economy

Analyses related to sustainability and CE frequently employ multi- or interdisciplinary approaches to better integrate non-economic aspects into development issues; they often conclude that system design and innovation are the main drivers of success (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). The CE may be considered a subset of the 'green growth' or 'green economy' concept (Horbach, Rennings, & Sommerfeld, 2015). It has been conceptualized as a system that is restorative by design and seeks to achieve greater resource efficiency through the reuse, remanufacture, and recycling of materials (Perey et al., 2018).

The CE has been proposed as a shift from an economy based on scarcity toward an economy based on resource-abundance solutions, including a series of innovations with ecosystem-like functions; these are expected to provide both economic and environmental benefits while also providing wider social benefits (Lieder & Rashid, 2016). Thus, the CE and eco-innovation may be understood as tools for achieving a green economy. In China, eco-industrial parks have been identified as important tools for realising the CE (Sarkar, 2013).

The interrelationship between eco-innovation and the closed-loop concept has been observed in the agribusiness sector in response to the few empirical studies on this subject (Dong-her et al., 2018). De Jesus et al. (2018) define a zone of overlap between eco-innovation and a CE based on pro-environment’ concepts, improved environmental performance and clean results, socially responsible benefits, and the holistic transformation required to introduce a circular business model to support holistic organisational innovation. Non-technological eco-innovations promoting new organisational models may support new schemes for increasing product use intensity through the sharing and upgrading of existing products to help close the materials loop (Mont, 2008). However, the CE requires not only innovative concepts but also innovative actors (Ghisellini et al., 2016). Moreover, given the evidence that the CE differs from eco-innovation (ESPON, 2018), some innovation scientists have started viewing the CE as a systemic innovation (Kirchherr & Piscicelli, 2019), and Katz Gerro & López Sintas (2019) define a firm’s patterns of CE engagement, which reflect the relationship between innovation in CE activities and organisational slack. This relationship influences the sociotechnical organisation, whereby the enterprise is stabilised by lock-in mechanisms but is engaged in incremental improvements.

Eco-innovation targets can differ from the specific targets of a CE. De Jesus et al. (2019) highlight the importance of rethinking technological and pro-circular innovation to implement systemic action grounded in an explicit innovation policy based on supply- and demand-side instruments and focused on cooperation between various actors. New business models based on leasing, rental, and “sharing” services also integrate the CE but need not be eco-innovative. Thus, the first research question (RQ1) aims to define and measure the overlaps between businesses’ eco-innovation and the potential CE-related activities adopted by firms:

RQ1: *Which business eco-innovation outcomes are more closely related to the activities introduced by firms for the CE?*

We do not explore the development of a new specific type of eco-innovation; rather, we contribute to the debate regarding the analysis and measurement of business eco-innovations that can be applied to the CE *sensu lato*, which we term ‘circular eco-innovation’.

2.2 Measurement of the impact of eco-innovation on the circular economy

Eco-innovation to achieve a CE has been identified as an opportunity to improve recycling and the use of circular strategies for raw materials and sourcing, manufacturing, product use and operation, and the recirculation of parts and products (Blomsma et al., 2019). Enhancing eco-innovation in the context of closed-loop supply chain management requires that all eco-innovation practices be improved and successfully implemented within a firm’s green innovation processes and environmental technologies. Moreover, regarding environmental technologies, knowledge sharing among partners/employees, green innovation process research and development, and cooperation with suppliers are all critical for enhancing circular business (Dong-her et al., 2018).

At a micro level, technology a key means of enabling circular loops; connecting demand and supply; and handling, storing, and managing the extensive volume of data a CE requires (Pomponi & Moncaster, 2017). Eco-design is a tool that can help incorporate environmental considerations into products, processes, or services and is well-suited for aiding businesses implement CE requirements (Mendoza, Sharmina, Gallego-Schmid, Heyes, & Azapagic, 2017). Eco-design is particularly salient throughout the analysis of circular innovation projects, for both product redesign and for promoting collaboration among supply chain partners (Franco, 2017).

Eco-innovation indicators have been used to measure aspects of the CE due to the similarity of their environmental aspects measured at the micro level. Smol et al. (2017) recommend five groups of indicators that could extend the measurement of eco-innovations with an emphasis on the development of regions, and Scarpellini et al. (2019) combine eco-innovation with CE-related principles at the regional level. However, these indirect CE-related indicators offer only an ancillary approach to assessing the CE (Moraga et al., 2019); few studies have empirically investigated the relationship between the introduction of CE-related activities in businesses and their level of eco-innovation. Therefore, a second research question is considered in this study:

RQ2: *How can circular eco-innovation be measured?*

Measuring circular eco-innovation allows us to enhance the analysis of the relations between eco-innovation outcomes and the level of CE introduced by firms, as is described in the following section.

2.3 Environmental capabilities and circular eco-innovation

Resources and capabilities have been demonstrated to be important to successful environmental management from the resource-based view (RBV) of the firm (Barney, 1991, 2001) and its extension to dynamic capabilities (Teece, Pisano, & Shuen, 1997). In recent years, the dynamic capabilities-based perspective has provided an appropriate theoretical basis for analysing the competitive advantage resulting from a firm's environmental improvements (Aragón-Correa & Rubio-López, 2007; Boiral, 2007; Essid & Berland, 2018; Iñigo & Albareda, 2016; Kabongo & Boiral, 2017; Katz Gerro & López Sintas, 2019). Within the dynamic capabilities framework (Eisenhardt & Martin, 2000; Teece et al., 1997; Zollo & Winter, 2003), a firm's competitive advantage emerges from its capacity to integrate, build, and reconfigure business competences to adapt to the changing business environment. A climate-induced competitive advantage could result in radical and competence-destroying reconfigurations of firm-specific advantages, as well as cleaner strategic reorientations and competence-enhancing investments (Daddi, Todaro, De Giacomo, & Frey, 2018).

Dynamic capability has been defined as the learned and stable pattern of collective activities through which an organisation systematically generates and modifies its operating routines to improve effectiveness (Zollo & Winter, 2003). Some authors highlight the importance of developing dynamic capabilities to support proactive environmental strategies through the adoption of non-formal EMSs (J Alberto Aragón-Correa & Sharma, 2003; Russo, 2009; Zhu, Cordeiro, & Sarkis, 2013). Path-dependent learning, such as that exemplified in ISO 14001 and similar cases, comprises an important aspect of the dynamic capabilities (Zhu et al., 2013) deployed when environmental management tools are adopted. In addition, certified EMSs have been differentiated from non-certified EMSs (i.e., whether there is an official standard certification guaranteeing EMS adoption), such as in the difference between formal and informal EMSs in terms of the level of formality of the EMS adoption (Amores-Salvadó, Martin-de Castro, & Navas-López, 2015; Iraldo, Testa, & Frey, 2009).

Recently, Demirel and Kesidou (2019) explicated EMSs in terms of specific sustainable-oriented capabilities for eco-innovation, highlighting its usefulness as a self-regulation instrument. Although this relationship has been widely defended and established from the RBV perspective, few authors recognise the role of dynamic capabilities when studying this relationship (e.g., Demirel and Kesidou, 2019; Hofmann et al., 2012; Kiefer et al., 2018). The studies claim that the development of dynamic capabilities is a determinant of eco-innovation and that EMSs are considered dynamic motivational and organisational firm capabilities.

In the eco-innovation literature, Del Río González (2005) shows that environmental management capabilities positively impact eco-innovation in companies that implement clean technologies. Firms' resources, competences, and dynamic capabilities determine their eco-innovations, and ecological certification such as ISO 14001 are considered useful indicators for measuring firms' motivational and organisational capabilities (Kiefer et al., 2018). In fact, firms' overall eco-innovation score can be determined by the ISO 14001 indicator (EOI, 2016).

The study of internal firm factors such as resources and capabilities from the CE perspective is at an early stage, and knowledge concerning how businesses understand and introduce the CE model is also limited. Although researchers advocating this view seem to agree on the importance of a firm's resources and capabilities to the CE, no study has explored ways of defining and measuring the environmental practices and capabilities that foster it.

As with eco-innovation, dynamic capabilities have been highlighted as determinants of the CE in business (Katz Gerro & López Sintas, 2019), and this theoretical approach has been used to identify the proactive environmental strategies that affect the sustainability of competitive advantage in the dynamic environments required for the CE (Garcés-Ayerbe et al., 2019; Inigo & Albareda, 2019).

We can also assume that a CE-related accountancy might integrate these specific capabilities because environmental management accounting (EMA) principally involves a reappraisal of how to identify and measure the costs of processes and products (Roger L. Burritt, 2004). The routines and processes of EMA imply a competence for making decisions related to dependence on environmental pressures and the increased costs of resources and materials, estimating impacts on the firm’s risk-management policy, and making investments in environmental improvement. Thus, both EMA and EMSs are considered in our study in a common framework of analysis within a CE context.

Scholars have demonstrated that EMSs improve environmental performance (Aravind & Christmann, 2011) and are potential conduits for developing firms’ environmental eco-innovation capabilities (Amores-Salvadó et al., 2015). The benefits for the CE of firms’ environmental capabilities and other resources related to their environmental performance have also been demonstrated (Aranda-Usón et al., 2019; Katz Gerro & López Sintas, 2019). However, the impact of formal and informal EMSs on the CE in businesses has not yet been empirically investigated. The possibility that both processes could share common capabilities merits exploration.

Thus, the following research question asks how firms’ environmental capabilities influence eco-innovation outcomes and overlap with CE-related activities (RQ3):

RQ3: *How do firms’ environmental capabilities applied to eco-innovation impact the development of a CE for them?*

To answer the three research questions, we measure the environmental capabilities applied to circular eco-innovation. Then, we propose an analytical model (see Figure 1) to study how environmental capabilities impact circular eco-innovation and the closing of material loops in businesses.

--- Insert Figure 1 about here ---

The methodological approach shown in Figure 1 is developed in the following section.

3. Method

3.1 Description of the sample

To achieve this study’s objectives, we design a survey (see the annex) based on previous surveys used with similar purposes. We solicit the cooperation of companies that have expressed an environmentally proactive intent by requesting their participation in a collaborative campaign that promotes eco-innovation and CE in north-eastern Spain in the framework of an R&D project. North-eastern Spain has high eco-innovation rates and thus offers data about eco-innovative firms at the regional level (Scarpellini, Portillo-Tarragona, & Marin-Vinuesa, 2019). We choose this region also due to its R&D potential: The region accounts for 44% of Spain’s business R&D investments while representing only 19% of the nation’s land mass, making it an important innovation hub in Europe (INE, 2019).

We select companies with more than 50 employees operating in sectors with the greatest potential for environmental investments and eco-innovation, such as those related to the technologies referred to in the ‘BREFs’ document (i.e. the ‘Best Available Techniques Reference’[1]). We use the 50-employees filter because firm size has been shown to have positive effects on the adoption of eco-innovation and CE measures (Rehfeld, Rennings, & Ziegler, 2007; Triguero, Moreno-Mondajar, & Davia, 2015; Wagner, 2007).

A population of approximately 1,000 companies is obtained. These are contacted by e-mail and are sent a survey on their eco-innovation activities relevant to a collaborative campaign. A total of 113 responses are obtained, of which 89 are considered valid (Table 1). The final response rate of 8.9% is considered statistically adequate, following recent empirical studies with similar aims and response rates (Demirel & Kesidou, 2019; Jabbour, Neto, Gobbo, Ribeiro, & De Sousa Jabbour, 2015; Littlewood, Decelis, Hillenbrand, & Holt, 2018). Though our sample may seem small, it is worth noting that we require that the surveys be answered only by managers with decision-making responsibilities and that the questionnaires be answered thoroughly. The companies were also identified by their Value Added Tax identification number (VAT ID), so the surveys were not anonymous. These requirements ensured the firms’ commitment to this research and the provision of high-quality answers, but they likely reduced the response rate.

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[1] See https://eippcb.jrc.ec.europa.eu/reference/ (accessed June 2019).

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--- Insert Table 1 about here ---

3.2 Measurement and variables

In designing the questionnaire, a first group of variables is selected to explore the intersection between eco-innovation and the CE-related activities introduced by businesses. We select these variables by first using measurement instruments similar to those used in other studies and then adding and elaborating variables specific to this study’s objectives (Aranda-Usón, Portillo-Tarragona, Scarpellini, & Llena-Macarulla, 2020; Marín-Vinuesa, Scarpellini, Portillo-Tarragona, & Moneva, 2018).

As mentioned, a wide set of indicators has been formulated for business eco-innovation, and specific variables for measuring the circular scope of firms have been developed in recent CE studies at a micro level (Aranda-Usón et al., 2019). However, circular eco-innovation has received scant attention (Demirel & Kesidou, 2019). Thus, four groups of eco-innovation inputs and outcomes are selected among those previously linked to business eco-innovation by Portillo-Tarragona et al. (2018) and Marín-Vinuesa et al. (2018).

From another perspective, measuring formal and informal EMSs while measuring eco-innovation activities conducted by companies allows us to evaluate the companies’ capacity for implementing the CE. In addition, several EMA variables are introduced because accounting has been identified by Burritt and Schaltegger (2001) as a tool for corporate environmental management, and EMA has been linked to various environmental processes (Roger Leonard Burritt, Herzig, Schaltegger, & Viere, 2019). In particular, accounting practices for identifying, classifying, and allocating the costs and risks of environmental issues must be considered part of the dynamic capabilities required for eco-innovation (Portillo-Tarragona et al., 2018).

Firms’ engagement in R&D is measured as the literature considers it a determinant of eco-innovation (Zubeltzu-Jaka, Erauskin-Tolosa, & Heras-Saizarbitoria, 2018), and it can have a particularly strong effect on a closed-loop sustainable supply chain because eco-innovative processes impact people’s values and lifestyles (Dong-her et al., 2018). Several aspects of corporate policy are also considered, following Stewart & Niero (2018). Finally, companies’ human resources (HR) policies, which have implications for employees, are considered because the impact of human capital is

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considered a determinant of eco-innovation (Ortega-Lapiedra, Marco-Fondevila, Scarpellini, & Llena-Macarulla, 2019).

Tables 2 and 3 offer a detailed description of the variables in our empirical model. The items used for each construct are measured in different ways: using a six-point Likert scale for the ECOD, ECOINV, ENER, R&D, and EHRP constructs, with 0 indicating ‘nothing‘ and 5 indicating ‘completely or to a large degree’; 2) using dichotomous items for the EMS, CGP, and EMA constructs, with 0 indicating ‘yes’ and 1 indicating ‘no’.; and 3) using a percentage scale (0%-100%) for the LOOP construct. *Circular eco-innovation* and *circular material loops* are the two main dependent variables.

--- Insert Table 2 about here ---

--- Insert Table 3 about here ---

3.3 Statistical analysis

We use structural equation modeling (SEM) to suit this study’s objectives and data structure. This technique is statistically supported by a combination of confirmatory factor analysis (measuring the relationships between items with latent variables through measurement models) and multiple regression analysis (measuring the relationships between latent variables through structural models). We employ SEM using a partial least squares (PLS) approach to measure, validate, and test the structural model. This methodology allows us to test the measurement and structural models simultaneously, and thus consider both the direct and indirect effects and analyse the mediating models in terms of causal inference.

We use PLS because we assume non-multivariate normality based on our measurement scales and Kolmogorov–Smirnov and Shapiro–Wilk tests for univariate normality ($p < 0.05$ for all items). In addition, PLS path modelling can predict key target constructs or, in exploratory research, identify key driver constructs (Hair, Ringle, & Sarstedt, 2011). Its sample size requirements are also comparatively low (Davcik, 2014; Fornell & Bookstein, 1982).

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We evaluate the reliability and convergent and discriminant validity of our variables using factor loading (λ), composite reliability (CR) indicators, and the average variance extracted (AVE) (Fornell and Larcker, 1981; Nunnally, 1978). To evaluate discriminant validity, we first applied Fornell and Larcker’s (1981) approach, which assumes that the square root of AVE should exceed the correlations between constructs. Additionally, we calculate the heterotrait–monotrait ratio of the correlations (HTMT), which is more sensitive to a lack of discriminant validity than are other criteria (Henseler, Ringle, & Sarstedt, 2014). Finally, to test predictive relevance, we analyse cross-validated redundancy using the Q^2 indicator proposed by Geisser (1974) and Stone (1974).

--- Insert Table 4 about here ---

4. Results

4.1 Main results

We estimate a two-order measurement model to analyse how firms’ environmental capabilities affect circular eco-innovation levels and impact CE performance levels in terms of closing the materials loop. First, using the multi-item scales for eco-design, eco-innovation investments, circular energy, and circular R&D initiatives, we construct four latent variables (ECOD, ECOINV, ENER and R&D, respectively). We then use these four latent variables as well as the variables from the multi-items scales for formal environmental management systems, eco-innovation human resources policy, corporate governance policy, environmental management accounting, and circular material loops (C-ECOI, EMS, EHRP, CGP, EMA and LOOP, respectively) for a second-order measurement model estimation.

Tables 4 and 5 describe the first- and second-order measurement models, respectively. They present different indicators to display the statistical power of our measurement models. All item loadings are greater than 0.65, the CR varies between 0.75 and 0.92, and the AVE ranges between 0.51 and 0.76. These values confirm the reliability and the convergent and discriminant validity of our variables. In terms of discriminant validity, both criteria highlighted by Fornell y Larcker (1981) – that the square root of the

AVE must always exceed the correlations between constructs and that the HTMT ratio between constructs should always be less than 0.72 – offer an acceptable level of support for our constructs.

After validating the final measures, we develop a structural equation model (see Figure 2). Specifically, we test for cause-and-effect relationships between the formal and informal environmental management tools, as specific environmental capabilities, and the circular eco-innovation level. In addition, we analyse the impact of circular eco-innovation on improvements in terms of closing the materials loop. Bootstrapping with 5,000 resamples was used to assess the significance of the path coefficients (Hair et al., 2011). Table 6 shows the estimation results for our research model in terms of coefficients (β), t-values, confidence intervals (CI), and R^2 and Q^2 indicators.

--- Insert Figure 2 about here ---

As expected, various environmental capabilities help develop circular eco-innovation initiatives. Thus, the estimated coefficients are positive and significant in the case of EMA (β=0.261, 97.5% CI= [0.100, 0.552]; p = 0.005), EHRP (β=0.337, 97.5% CI= [0.014, 0.454]; p = 0.020) and CGP (β=0.222, 97.5% CI= [0.039, 0.380]; p = 0.012) but are not significant in the case of EMS (β=0.155, 97.5% CI= [-0.230, 0.320]; p = 0.233). Therefore, we show that, whereas new forms of informal environmental management tools such as EMA, environmental HR, and corporate governance are effective in promoting circular eco-innovation, traditional EMSs have lost their effectiveness and are not able to support new circular eco-innovation developments. In addition, the coefficient estimating the impact of circular eco-innovation on closing the materials loop is also positive and significant (β=0.371, 97.5% CI= [0.046, 0.584]; p = 0.006). Thus, we observe that circular eco-innovation initiatives such as eco-design, circular energy, eco-innovation and R&D contribute to foster CE achievement.

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The explained variances ($R^2 > 0.10$) show an acceptable level of explanatory power (Falk & Miller, 1992). We also analyse the cross-validated redundancy to evaluate the predictive relevance of our estimations. Our model shows positive Q^2 values for the two dependent variables, which suggests that the model has predictive validity (Chin, 1998). In the next section, we analyse the possible indirect or mediated effects to gain additional insight into the impact of specific environmental capabilities on CE achievement.

4.2 Post hoc analyses of indirect effects

Our estimations show that some environmental capabilities affect CE performance indirectly in terms of the closing of materials loops. Table 6 includes detailed information about these mediating effects. On the one hand, as expected, the EMS construct has no significant indirect effect on LOOP (β=0.058, 97.5% CI= [-0.052, 0.197]; p = 0.337). On the other hand, our estimations find positive and significant indirect effects for the EMA constructs (β=0.125, 97.5% CI= [0.016, 0.297]; p = 0.006), CGP (β=0.082, 97.5% CI= [0.007, 0.189]; p = 0.006) and EHRP (β=0.097, 97.5% CI= [0.015, 0.246]; p = 0.006).

These results confirm that, unlike for formal EMSs, the effect of informal environmental management tools – as specific environmentally effective capabilities – goes beyond the level of circular eco-innovation and indirectly impacts CE performance, helping intensify circular material loops.

4.3 Discussion and main implications

This study defines and measures the activities related to circular eco-innovation implemented by businesses in order to investigate its first and second research questions (RQ1 and RQ2). Four groups of eco-innovation inputs and outcomes are considered to be directly or indirectly related to CE implementation: investments in eco-innovation, eco-design practices, investments and improvements in renewables and innovative equipment or processes for energy efficiency, and R&D investments to support environmental improvement. These indicators enhance the insights achieved by Portillo-Tarragona et al. (2018) and Marín-Vinuesa et al. (2018) and confirm the findings of Franco (2017), who analysed product redesign in eco-innovative projects from a circular approach focusing on collaboration among supply chain partners.

In this study, eco-innovations to support energy efficiency and the exploitation of renewables are considered important investments in the CE, and feature in the debate concerning the connections between energy transition and the CE. Moreover, the level of environmental R&D, which has been highlighted as a suitable indicator for measuring eco-innovation (Portillo-Tarragona et al., 2018), has been analysed within the CE framework (RQ1).

Measuring the indicators proposed by Aranda-Usón et al. (2020) for the CE within a common framework with eco-innovation facilitates the introduction of the CE through innovative activities designed to achieve closed material loops (RQ2). This enriches earlier studies focused on circular business models (Perey et al., 2018) by reconceptualising the role of eco-innovation from a CE perspective.

Several authors argue that eco-innovation for the CE is usually incremental (de Jesus & Mendonça, 2018; Katz Gerro & López Sintas, 2019), thus suggesting that the environmental component of eco-innovation is more important than the innovation process required in one radical type. In our study, the definitions of the common environmental capabilities applied to firms' eco-innovation and CE-related activities (RQ3) contribute to the prioritisation of the environmental aspects of eco-innovative investments, consistent with Portillo-Tarragona et al. (2018).

The results of this study confirm that the effect of informal environmental management tools, unlike that of formal EMSs, goes beyond the level of circular eco-innovation to indirectly impact firms' CE performance, thus helping to intensify circular material loops. These results contribute to the emerging debate on the importance of environmental management certification in the implementation of the CE. We confirm the results that Prieto-Sandoval et al. (2018) empirically could not and the results obtained by Demirel y Danisman (2019) are here enhanced.

New informal environmental management tools such as EMA and environmental HR and corporate governance are effective at promoting circular eco-innovation, whereas traditional EMSs have lost their effectiveness and are unable to support new circular eco-innovation developments. These findings enhance the measurement range and scope of CE-related activities and circular eco-innovation for analyses taking corporate social responsibility (CSR), the sustainability accounting perspectives or the corporate sustainability of funds (Alda, 2019) and the corporate governance (Ortas, Gallego-Álvarez, & Álvarez, 2019; Zubeltzu-Jaka, Andicoechea-Arondo, & Alvarez Etxeberria, 2018).

The adoption and implementation of an EMS can lead to a standard certificate. However, an EMS goes beyond simple environmental certification to include internal efforts at policymaking, assessment, planning, and implementation, which generally follow a continuous improvement model that, through management processes, can enable organisations to continually reduce their environmental impact (Darnall & Edwards, 2006). This study’s findings indicate that EMSs play an important role in the implementation of eco-innovation in different industries, thus enhancing the results in Dong-her et al. (2018) regarding circular agribusiness.

As mentioned, the consensus is that EMSs are effective drivers of eco-innovation. However, an important group of authors has expressed doubts about the environmental aspect of EMS certification. The literature has provided inconclusive evidence on whether EMS certification improves environmental performance (Amores-Salvadó et al., 2015) and this study contributes to this debate, and particularly to the CE literature.

The existence of an EMS helps businesses identify profitable innovation opportunities related to environmental sustainability and the CE. Consequently, we can affirm that the EMS can assist in the development of the conditions under which environmental capabilities can be deployed to implement CE-related activities in businesses, similarly to how these capabilities contribute to the incorporation of environmental considerations into a firm’s business strategy (Darnall & Edwards, 2006). In particular, the capabilities that foster the material loops closing and the related cost saving have to be developed in the CE framework: eco-design focused on the dematerialisation for the resource saving, investments in renewables and energy efficiency for the energy saving, and R&D investments to support environmental improvement of the company for the emission saving.

5 Conclusions

This study defines and measures formal and informal EMSs and other management and accounting procedures that are applied to circular eco-innovation within the dynamic capabilities theoretical framework. We enhance our knowledge on the CE at the micro level through a twofold transversal approach to theoretical and methodological issues. The environmental capabilities firms apply to eco-innovative processes are redefined from a CE perspective to address a gap in the literature. We also open a new line of inquiry in the sustainability literature about environmental management tools and EMA applied to the CE.

Using a research approach initiated by earlier authors conducting micro analyses, we provide empirical support to the view that firms’ CE-related activities behave similarly to eco-innovation, and we also offer new insights that can help future business researchers examine the common firm capabilities that can help introduce the CE, particularly when eco-innovation has already been performed.

At present, the measurement of a firm’s CE at the corporate level is a topic of significant research interest because such indicators have yet to be developed. This approach constitutes a novelty research because different variables have been designed to measure the endogenous EMA procedures firms apply to carry out circular eco-innovation.

This study’s results offer insights to practitioners seeking to understand how to manage the competences that integrate the capabilities used in decision making regarding investments in circular eco-innovation and in order to improve those capabilities that influence more than others the CE due to their positive impact on the material loops closing. This integrated measurement allows us to examine firm investments in the CE and can be applied to a large number of firms, regardless of their size or industry.

The definition of the interaction between eco-innovation and the CE analysed in our research should help policymakers design national and local policies for promoting circular eco-innovation and achieving the intersection of innovation and materials loop-closing, thus fostering a more sustainable future.

This study’s limitations mainly concern its empirical foundation and method. First, the measurement of the degree of circularity and circular economy performance accounts for only materials loop-closing. As our work is pioneering, it uses new measures related to eco-innovation and the CE. This novelty may explain the limited values in the materials loop-closing variance indicator. Although the model’s explanatory power for this dependent variable is statistically acceptable, additional testing and adjusting of our measures could improve our results. Second, the data collection approach prioritises the firms’ commitment to this research and the quality of their survey answers, leaving a limited number of companies in the final sample. Using more firms and examining different regional contexts could provide an additional perspective on the issues considered in this study. Third, using a survey to capture business data provides only a lateral view of firms’ environmental capabilities for eco-innovation and the CE. It is important to investigate trends over a longer period and obtain longitudinal data illuminating the development of the dynamic capabilities firms apply to the CE.

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7 References

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8 Annex

--- Insert Figure 3 about here ---

Post-print version of:
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Table 1. Description of sample.

		Population		Sample	
Variable	Description	N	%	N	%
Size: Number of employees	From 50 to 250 employees	1,566	70.19	59	66.29
	From 251 to 450 employees	386	17.30	14	15.73
	More than 450 employees	279	12.51	16	17.98
		2,231	100	89	100
Sector	Mining	13	0.58	1	1.12
	Manufacturing	1,040	46.62	36	40.45
	Energy	601	26.94	23	25.84
	Water Supply	64	2.87	8	8.99
	Transport & Storage	513	22.99	21	23.60
		2,231	100	89	100

Table 2. Description of circular eco-innovation items

Construct/Item	Construct/Item Description	Mean	SD
Eco-Innovation output applied to the circular economy: CIRCULAR-ECO-INNOVATION (C-ECOI)			
Construct: ECOINV	*Eco-Innovation Investments*		
ECOINV1	% of total revenue invested in environmental R&D (internal or external) for eco-innovations	2.48	1.46
ECOINV2	% of components of the product or service that have been replaced by innovative ones to comply with environmental regulations	3.56	2.21
ECOINV3	% of total revenue invested in innovative equipment/machinery to reduce the company’s environmental impact	1.76	1.11
ECOINV4	% of resources replaced by other fully recycled materials to manufacture products or provide services	1.54	1.37
Construct: ECOD	*Eco-Design*		
ECOD1	% of product design or services modified to reduce resource intensity (dematerialisation)	2.26	1.43
ECOD2	% of product design or services modified to increase function (multifunction)	2.38	1.65
ECOD3	% of product design or services modified to extend life	2.32	1.43
ECOD4	% of product design or services modified to increase recyclability (waste prevention)	2.54	1.60
Construct: ENER	*Circular Energy*		
ENER1	% of equipment or facilities replaced and/or improved to reduce energy consumption	2.91	1.52
ENER2	% of processes and operating procedures replaced or improved to reduce energy consumption or exploit renewables	2.51	1.57
ENER3	% of total revenue invested in incinerating waste or energy recovery	1.47	0.63
ENER4	% of total revenue invested in renewables facilities	1.43	0.86
Construct: R&D	*Circular R&D*		
R&D1	% of total investments in R&D devoted to environmental issues, eco-design, or similar processes financed by the company’s own funds	2.19	0.86
R&D2	% of the investments in environmental R&D, eco-design, or similar processes of the total company’s investments	2.65	1.42
R&D3	% of investments in environmental R&D, eco-design, or similar processes that are financed with public funds	2.58	1.16
R&D4	% of investments in environmental R&D that are financed with foreign funds	2.30	1.35
Construct/Item	Construct/Item Description	Mean	SD
Circular material loops			
Construct: LOOP	*Circular Material Loops*		
LOOP1	% of local waste recovery and reuse	10.91	26.93
LOOP2	% of waste recovery and reuse within the company	1.09	4.94
LOOP3	% of local recycling waste (treated to be recycled)	17.24	33.42
LOOP4	% of recycling waste within the company (treated to be recycled)	1.78	10.19

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Table 3. Description of environmental capabilities items

Construct/Item	Construct/Item Description	Mean	SD
Environmental capabilities for eco-innovation and the CE			
Construct: EMS	*Formal Environmental Management Systems*		
EMS1	Has the company implemented the ISO 14001 standard?	0.73	0.44
EMS2	Has the company implemented the ISO 14006 standard?	0.10	0.42
EMS3	Has the company implemented the ISO 50001 standard?	0.23	0.31
Construct: EHRP	*Eco-Innovation Human Resources Policy*		
EHRP1	Level to which the company fosters the horizontal development of HR	3.42	1.29
EHRP2	Level to which the company develops training programs for HR to implement eco-innovation and/or eco-design	2.27	1.47
EHRP3	Level to which the company considers the competencies for innovation of HR in the recruitment phase	2.39	1.44
EHRP4	Level to which the company incentivises the generation of innovative ideas	1.95	1.64
Construct: EMA	*Environmental Management Accounting*		
EMA1	Has the company posted entries related to environmental activities and investments and specific information concerning sustainability?	0.41	0.49
EMA2	Has the company posted accounting provisions and contingences for environmental investments and risks?	0.57	0.50
EMA3	Has the company detailed environmental accounting issues and entries in its financial reports?	0.51	0.51
Construct: CGP	*Corporate Governance Policy*		
CGP1	Does the company have a specific and public policy on reporting and accountability?	0.76	0.43
CGP2	Does the company apply and disseminate a corporate governance code?	0.78	0.42

Table 4. Outer Model Loadings and Cross-loadings (1st order).

	ECOD	ECOINV	ENER	R&D
ECOD1	**0.838**	0.369	0.309	0.294
ECOD2	**0.789**	0.463	0.279	0.335
ECOD3	**0.870**	0.466	0.422	0.439
ECOD4	**0.860**	0.431	0.365	0.522
ECOINV1	0.469	**0.880**	0.471	0.609
ECOINV2	0.484	**0.821**	0.408	0.473
ECOINV3	0.260	**0.686**	0.470	0.325
ECOINV4	0.348	**0.715**	0.494	0.299
ENER1	0.325	0.523	**0.800**	0.497
ENER2	0.382	0.427	**0.854**	0.489
ENER3	0.382	0.315	**0.688**	0.294
ENER4	0.273	0.532	**0.841**	0.456
R&D1	0.418	0.559	0.559	**0.888**
R&D2	0.459	0.486	0.396	**0.845**
R&D3	0.381	0.413	0.351	**0.847**
R&D4	0.447	0.527	0.578	**0.876**
CR	0.905	0.860	0.875	0.922
AVE	0.705	0.607	0.637	0.747
Fornell and Larcker criterion				
ECOD	*0.840*			
ECOINV	0.517	*0.779*		
ENER	0.418	0.574	*0.798*	
R&D	0.495	0.580	0.558	*0.864*
HTMT criterion				
ECOINV	0.600			
ENER	0.495	0.723		
R&D	0.537	0.643	0.626	

All λ in bold are significant at $p < .00$.
CR: Composite Reliability; AVE: Average Variance Extracted; HTMT: Heterotrait–monotrait ratio.
Correlations/HTMT are below the diagonal, and the square root of the average variance extracted (AVE) is in italics on the first diagonal.

Table 5. Outer Model Loadings and Cross-loadings (2nd order).

	LOOP	C-ECOI	EHRP	CGP	EMA	EMS
LOOP1	**0.862**	0.327	0.090	0.224	0.313	0.101
LOOP2	**0.859**	0.317	0.078	0.218	0.323	0.097
LOOP3	**0.845**	0.310	0.169	0.079	0.347	-0.083
LOOP4	**0.854**	0.315	0.177	0.089	0.354	-0.083
ECOD	0.247	**0.671**	0.049	0.185	0.111	0.197
ECOINV	0.257	**0.766**	0.131	0.232	0.328	0.035
ENER	0.294	**0.765**	0.153	0.295	0.350	0.103
R&D	0.288	**0.729**	0.228	0.098	0.320	0.075
EHRP1	0.168	0.235	**0.783**	0.032	0.149	0.103
EHRP2	0.152	0.312	**0.801**	0.044	0.072	0.175
EHRP3	0.049	0.274	**0.744**	0.152	0.086	0.053
EHRP4	0.086	0.212	**0.729**	0.226	0.009	-0.033
CGP1	0.212	0.258	0.232	**0.873**	0.051	-0.109
CGP2	0.064	0.195	-0.039	**0.763**	0.129	-0.023
EMA1	0.451	0.372	0.135	0.053	**0.929**	-0.079
EMA2	0.279	0.209	0.047	0.097	**0.801**	-0.067
EMA3	0.279	0.368	0.076	0.126	**0.893**	-0.027
EMS1	0.133	0.084	0.056	-0.106	0.002	**0.656**
EMS2	-0.068	0.093	0.052	-0.016	-0.159	**0.677**
EMS3	-0.021	0.124	0.115	-0.068	0.007	**0.804**
CR	0.916	0.823	0.849	0.803	0.908	0.757
AVE	0.731	0.538	0.585	0.672	0.768	0.512
Fornell and Larcker criterion						
LOOP	*0.855*					
C-ECOI	0.371	*0.734*				
EHRP	0.150	0.344	*0.765*			
CGP	0.180	0.280	0.140	*0.820*		
EMA	0.391	0.377	0.105	0.102	*0.876*	
EMS	0.011	0.143	0.109	-0.087	-0.063	*0.715*
HTMT criterion						
C-ECOI	0.468					
EHRP	0.182	0.454				
CGP	0.249	0.448	0.301			
EMA	0.443	0.463	0.131	0.173		
EMS	0.212	0.247	0.213	0.189	0.176	

All λ in bold are significant at $p < .00$.

CR: Composite Reliability; AVE: Average Variance Extracted; HTMT: Heterotrait–monotrait ratio.

Correlations/HTMT are below the diagonal, and the square root of the average variance extracted (AVE) is in italics on the first diagonal.

Table 6. Structural Model Results.

	C-ECOI	LOOP	t Value	97,5% bias corrected and accelerated confidence interval
Direct effects				
EMS	0.155		1.193	(-0.230 – 0.320)
EHRP	0.337^{*}		2.322	(0.014 – 0.454)
CGP	0.222^{**}		2.522	(0.039 – 0.380)
EMA	0.261^{***}		2.817	(0.100 – 0.552)
C-ECOI		0.371^{***}	2.769	(0.046 – 0.584)
Indirect effects				
EMS		0.058	0.961	(-0.052 – 0.197)
EHRP		$0.097^{\Diamond}$	1.506	(0.015 – 0.246)
CGP		$0.082^{\Diamond}$	1.750	(0.007 – 0.189)
EMA		$0.125^{\Diamond}$	1.739	(0.016 – 0.297)
R^2	0.310	0.138		
Q^2	0.020	0.010		

$^{***}p < 0.00$ $^{**}p < 0.01$ $^{*}p < 0.05$ $^{\Diamond}p < 0.10$