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Circular economy adoption by European small and medium-sized enterprises: influence on firm performance

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Abstract

Purpose – This study aims to analyze the elements that influence the adoption of circular economy (CE) activities by European small and medium enterprises (SMEs) and how these activities affect firm performance, following a multi-level approach.

Theoretical framework – To improve essential transformations, CE implementation must take place simultaneously in the micro, meso, and macro systems (multi-level approach); this is necessary to help underscore the holistic, systemic change that the CE requires. Furthermore, it is hard for SMEs to visualize the economic benefits, as the implementation of CE practices often involves making additional investments that SMEs may not consider profitable.

Design/methodology/approach – We developed seven hypotheses and a theoretical model based on the literature review to answer the research question. The model and hypotheses were tested using the path analysis method, applying the model to a sample of 4,550 European SMEs. Our empirical analysis uses data from the Flash Eurobarometer 441 (European SMEs and the Circular Economy) and the 2016 EUROSTAT database.

Findings – The results support the idea that the financial impact of adopting a CE is positive and is affected by the level of national economic and environmental performance.

Practical & social implications of research – By connecting the emergence of the CE to the national context, our study highlights the importance of considering macro-level factors when analyzing the impact of CE adoption on firm performance. Public direct investment policies, especially in countries with higher economic performance rates where firms operate at a higher level of competitiveness, can improve firm performance indicators and make CE adoption more attractive.

Originality/value – Studies on the exploration of the CE have a predominance of qualitative research with a single case; however, as the CE is a practice-oriented paradigm, the use of a quantitative methodology has become crucial to research articles in this field. This paper develops frameworks and metrics for assessing the CE at the country, industry, and firm levels using a quantitative methodology.

Keywords: Circular economy, firm performance, SMEs, multi-level.

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1 Introduction

The importance of the circular economy (CE) in the plans of policymakers and in the discussions inside firms has grown in recent times. The debate of policymakers concerning this subject emerges from the various policies implemented, such as the European Circular Package and the Chinese Circular Economy Promotion Law, and the engagement of many firms in the discussion due to thematic organizations such as the Ellen McArthur Foundation, which has promoted many studies in this area (Geissdoerfer et al., 2017).

CE implementation studies follow a multi-level approach (Ghisellini et al., 2016), considering the existence of a macro, meso, and micro level (ibid.). The macro level aims to adjust the industrial composition and structure of the entire economy, and it can be global, national or regional, with legislation as the central instrument of action; the meso level focuses on industrial symbiosis, that is, the inter-company level, as it involves physical exchanges between multiple organizations (Chertow, 2000); and the micro level mainly considers individual enterprises (Feng & Yan, 2007; Ghisellini et al., 2016; Kirchherr et al., 2017; Merli et al., 2018).

At the micro level, CE studies have been developed mainly focusing on large industries, and it is observed that the practice is not sufficiently widespread across small and medium-sized enterprises (SMEs) (Ormazabal et al., 2018). Despite the fact that 99% of firms in the European Union (EU) are SMEs and that these firms create the majority of new jobs, research focusing on CE activities conducted by SMEs is scarce. Evidence of the relevance of SMEs in this field is that the EU has recently funded some projects fostering CE practices in these types of firms (European Commission, 2020a). Exceptions are some recent articles that specifically focus on the barriers and enablers of SMEs for implementing a CE (Cantú et al., 2021; Mura et al., 2020; Rizos et al., 2016; Scipioni et al., 2021). SMEs seeking CE activities are more likely to face additional costs because of their low bargaining power among stakeholders in the supply chain (Rizos et al., 2016; Van Eijk, 2015; Wycherley, 1999). For SMEs, it is hard to visualize the economic benefits as the implementation of CE practices often involves making additional investments that SMEs may not consider profitable (Dalhammar, 2016). Thus, *our aim is to analyze the factors that influence SMEs to adopt CE activities and how these activities affect firm performance.* Furthermore, to improve the essential transformations, CE implementation must take place simultaneously in the micro, meso, and macro systems; this is necessary to underscore the holistic, systemic change that a CE requires (Khitous et al., 2020; Kirchherr et al., 2017). To support this theory, we also test whether CE outcomes at the micro (firm) level are influenced by the macro (country) level. We assume that countries with better CE performance will provide firms with better results when they implement CE activities.

2 Literature review

The term CE was first used by Peace and Turner in 1990, when they inferred how the use of natural resources as inputs of industries impacts the economy and, at the same time, how the outputs of the same industries impact them (Andersen, 2007; Geissdoerfer et al., 2017; Ghisellini et al., 2016; Merli et al., 2018; Reike et al., 2018; Su et al., 2013). The term "circular economy" has been associated with a number of meanings in different research, but they generally share the concept of a cyclical closed-loop system (e.g., Bocken et al., 2016; Murray et al., 2017; Stahel, 2016, 2019).

In 2006, the CE started to be formalized and delineated by Chinese policy, which included the CE as the main purpose of national economic and social development plans (Su et al., 2013). In this effort, the Chinese "Circular Economy Promotion Law" aimed at "[...] improving resource utilization efficiency, protecting the natural environment and realizing sustainable development" (Geng et al., 2012, p. 216). In Europe, the CE emerged later with the launch of the Circular Economy Package (Masi et al., 2017). Other countries implemented the CE with different approaches as a guideline (George et al., 2015). Thus, the definition of CE became notorious and researchers started to use it (Ghisellini et al., 2016).

A CE is typically implemented in firms (micro-level), considering two main areas of eco-innovation (EI): eco-design (a type of product innovation) and clean production (a type of process innovation) (Jesus & Mendonça, 2018; Ghisetti et al., 2017). Eco-design, as a product innovation, occurs in different forms, such as through the use of recycled materials or the redesign of products and services to reduce raw material use (Demirel & Danisman, 2019). Regarding clean production, as an innovation process, we can mention redesigning water usage to minimize the expenditure of this resource by promoting reuse, using renewable energy, redesigning to minimize

energy usage, and reducing waste by recycling, reusing, or selling to other firms. These are typical examples of EI processes that use the principles of subsystem or system change to increase the eco-effectiveness of operations (Demirel & Kesidou, 2019; Kiefer et al., 2019). While product innovations improve performance by expanding the firm's market share or facilitating its entry into new markets, process innovations do so by increasing efficiency and lowering costs (Coad et al., 2016; Doran & Ryan, 2016).

On this practitioner side, the Ellen MacArthur Foundation has a critical responsibility to encourage the adoption of CE practices among firms, being considered a reference in such practices (Merli et al., 2018). It has carried out several evaluations confirming that the implementation of CE activities leads to considerable cost reductions (Ellen MacArthur Foundation, 2015). The CE became a policy priority of the EU, among other proposals, in response to high commodity prices and lack of resources.

Some researchers have found that investing in CE can have positive effects on firm performance (e.g., Aboulamer, 2018; Demirel & Danisman, 2019; Geissdoerfer et al., 2017; Kirchherr et al., 2017; Moric et al., 2020). Aboulamer (2018) argued that adopting activities related to the CE extends the useful life of products while minimizing resource use and waste, which could be directly reflected in improved financial performance. Firms could benefit from CE adoption through cost savings achieved by reducing the use of raw materials (e.g., metals and energy) or by creating new markets (Taranic et al., 2016). In other words, the large-scale adoption of the CE by firms as a new business model will contribute to the use of resources in multiple cycles and the reduction of waste and consumption (Lüdeke-Freund et al., 2019). These arguments support the first hypothesis.

Hypothesis 1: CE adoption is positively associated with firm performance.

Rizos et al. (2016) analyzed the frequency of different barriers to CE adoption mentioned by SMEs. The authors understood that this is an indication of how SMEs feel when confronted with a barrier. The study concluded that various barriers pose a challenge to SMEs in their transition to a CE (Rizos et al., 2016).

Lack of capital is a relevant barrier for smaller companies (Hollins, 2011; Rademaekers et al., 2011). Kirchherr et al. (2018) found that high upfront investment costs are one of the most pressing barriers to CE adoption, as working with a CE involves a significant adjustment in business planning and strategy, and this shift causes additional investments. Some of the findings of Rizzo's study reveal the concerns of SMEs: "Because of our low turnover, banks have always been hesitant in releasing funding to the business. It has been very challenging to secure a sufficient amount of funds to run our core business, let alone for greening the business" (Rizos et al., 2016, p. 12). Neubaum et al. (2004) argued that this lack of resources and concern for survival could have a negative impact on CE adoption. The authors believe that leaders may use the argument of high upfront investment costs to abandon a CE initiative (ibid.).

Another important barrier is the lack of technical skills. The transition to a more circular business requires a fundamental rethinking of industrial processes and organizations (Wautelet, 2016). In some situations where SMEs intend to improve the environmental performance of their business, they are hindered by this barrier. In the study by Kirchherr et al. (2018), it was assessed that there is a learning cost to implement a CE, and some firms wait for others to invest first and move up the learning curve. As a result, the current staff, in many cases with insufficient knowledge, operates the new technology, which jeopardizes its adoption. Usually, the lack of technical skills is not the only barrier, as it is usually correlated with a lack of resources and time for training to acquire the necessary skills. Overall, "[...] technical bottlenecks stand out as the perceived source of the greatest challenges" (Jesus & Mendonça, 2018). In this study, we use the term "lack of technical skills" as the: i) lack of human resources (Garcés-Ayerbe et al., 2019; García-Quevedo et al., 2020), ii) lack of competence to implement a CE (Calogirou, 2010; Liu & Bai, 2014; Rademaekers et al., 2011; Van Eijk, 2015), and iii) lack of knowledge regarding the benefits and necessary investments (Amec, 2013; Murillo-Luna et al., 2011; Rizos et al., 2016).

In contrast to the barriers, organizational strategy is a critical enabler for CE businesses. Generally, firms with a differentiation strategy (Porter, 1980) are more likely to be sensitive to changes in the markets and to create capabilities to meet these changes (Koza & Lewin, 1998). According to Aboulamer (2018), the relationship between R&D investment and green activities is well established in the literature, and it is possible that this relationship could extend to the adoption and implementation of CE principles. Companies that invest heavily in R&D activities

tend to develop more internal innovation capabilities, which can enable them to develop new technologies, materials, and processes that are consistent with CE principles. In addition, companies that invest in R&D may be more likely to adopt CE principles because they tend to be more aware of the potential benefits and opportunites associated with this new economic paradigm. Therefore, it is possible that R&D investment could be a key driver of the adoption and implementation of CE principles. The study by Yamakawa et al. (2011) uses R&D as an indicator of the level of differentiation strategy, and our study replicates the same logic. Considering these factors that positively or negatively influence CE adoption, we expect that:

> Hypothesis 2a: A firm's choice of differentiation strategy is positively related to CE adoption.
>
> Hypothesis 2b: A firm's lack of technical skills is negatively related to CE adoption.
>
> Hypothesis 2c: A firm's financial capacity is positively related to CE adoption.

Although all EU countries are subject to the same set of policies regarding CE and recycling targets (Sakai et al., 2011), national plans, financing systems, institutional context, and incentives are still very heterogeneous across countries, and this affects the involvement of SMEs in CE activities (Zamfir et al., 2017). Bačová et al. (2016) stated that geographical, environmental, economic, and social factors influence the CE. For example, factors such as the accessibility of the region can play a role: in less accessible areas, the sharing economy could be a major challenge (ibid.). Analyzing the ESPON GREECO report (Hansen et al., 2014), Bačová et al. (2016) showed that firms in higher performance countries may need less support in the transition to a CE than those in low performance regions. This is because countries with lower environmental performance do not have sufficient enforcement of environmental regulations, which does not encourage companies to adopt a circular business model. The lack of adequate market signals, such as low raw material prices, also reinforces this scenario. It induces firms to purchase cheaper raw materials instead of using recycled ones, which often entails additional processing costs (Bicket et al., 2014). Similar discrepancies occur in other policy instruments, such as the lack of "consumption taxes" to charge for the use of polluting products, which could inhibit their adoption by consumers (Geng & Doberstein, 2008). The diversity of territorial contexts translates into different needs and opportunities that any CE should address (Bačová et al., 2016). Not only environmental regulations in the national context affect the involvement of SMEs in CE activities, but also geographical location (access) and market (price of raw materials) factors. The main issue is that firms in higher performing countries may need less support in the transition to a CE than those in low performing regions. And this is what the model proposes to test: whether the country's performance influences the transition. Exploring the CE in the context of sustainable developmentcould be a valuable goal to improve the efforts of policymakers, companies, and society at large. In the context of CE performance, there is a need for adequate monitoring with indicators (Bačová et al., 2016). The EASAC (2016) defines an interesting approach to CE indicators for sustainable development, which consists of a panel of indicators that are divided into the following groups: environment, material flow analysis, societal behavior, organizational behavior, and economic performance. In other words, these indicators represent the main objectives of sustainable development. In order to carry out valuable economic, social, and environmental analyses, it is necessary to adapt to the situation of each country. Considering these arguments, we hypothesize that:

> Hypothesis 3a: The economic performance of the country in which the SME is located positively moderates the relationship between CE adoption and firm performance.
>
> Hypothesis 3b: The social performance of the country in which the SME is located positively moderates the relationship between CE adoption and firm performance.
>
> Hypothesis 3c: The environmental performance of the country in which the SME is located positively moderates the relationship between CE adoption and firm performance.

3 Method

We developed seven hypotheses and a theoretical model based on the literature review to answer the research question. The model and hypotheses were tested according to the path analysis method, which is an extension of the

regression model (Garson, 2013). A regression is performed for each dependent variable that the model suggests has causes. The observed correlation matrix for the variables is compared to the regression weights predicted by the model, a goodness-of-fit statistic is calculated, and the best model is chosen for the theory development (Garson, 2013). As shown in Figure 1, the model is composed of eight variables, which are: i) firm strategy; ii) technical skills; iii) financial capacity; iv) CE adoption; v) firm performance; vi) economic performance; vii) social performance; and viii) environmental performance. The variables from i) to v) are related to the micro level of analysis (firm) and the rest are related to the macro level of analysis (country). We also use the following control variables: age, sector, consumer type and size.

3.1 Description of the data

Our empirical analysis uses data from the Flash Eurobarometer 441 (European SMEs and the Circular Economy), a self-reported business survey conducted in the 28 EU countries in 2016, including 10,618 interviews (European Commission, 2016), to measure the endogenous variables and the micro-level exogenous variables (described in the next section). Despite its limitations in terms of its cross-sectional nature (which makes it difficult to establish causal relationships) and its reliance on Flash technology (specifically, computer-assisted telephone interviewing – CATI – which can introduce respondent bias), the survey we use as a baseline includes a wide range of questions. These questions serve as the basis for constructing the variables used in our analysis (Supplementary Data 1 – Description of variables and codes). Moreover, these data have been used by a significant number of studies (e.g. Bassi & Dias, 2019; Demirel & Danisman, 2019; Ghenţa & Matei, 2018; Kalar et al., 2021; Moric et al., 2020; Zamfir et al., 2017). For this research, we excluded firms that lacked relevant information for our analysis. Therefore, our final sample contained 4,550 observations (Supplementary Data 2 – database).

Additional data from the 2016 EUROSTAT database were used to measure the exogenous macro-level, or country-level, variables of the analysis. The circular material use rate was used to measure environmental performance and gross domestic product was used to measure economic performance. Social performance was extracted from the Human Development Report, using the 2016 Human Development Index (HDI) of the countries included in this research.

3.2 Model variables

3.2.1 *Endogenous variables*

Following previous reports (Delmas & Pekovic, 2018; Friesenbichler & Peneder, 2016; Li, 2020; Moric et al., 2020), our dependent variable, called "firm performance," was expressed as the logarithm of sales per employee (in euros). As a measure of productivity, it allows for cross-country comparisons as it is not influenced by firms' accounting and financing decisions (Li, 2020). Limitations of this measure include the fact that it does not account for intermediate inputs. In addition, the availability of this measure for all firms is not guaranteed and the use of alternative measures (such as value added

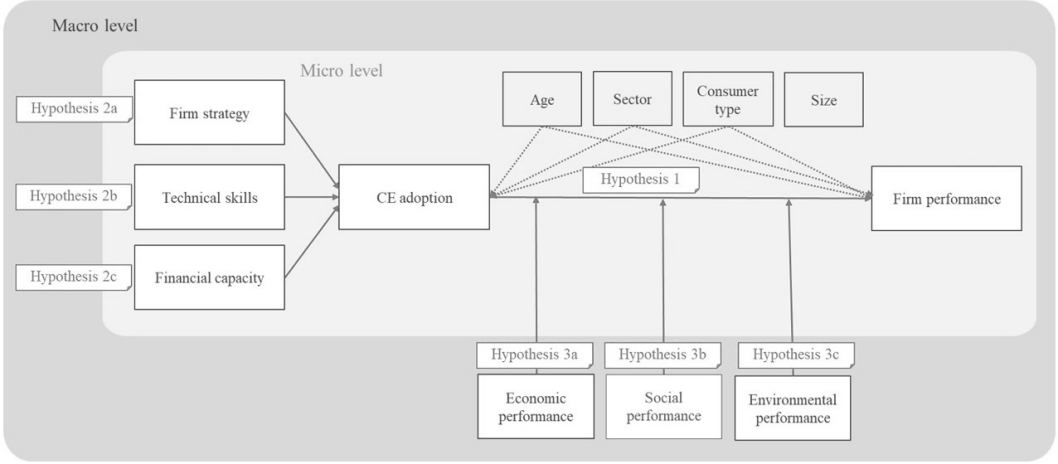

Figure 1. Empirical model

per employee) may reduce the sample size (Friesenbichler & Peneder, 2016).

The 3R imperatives of "reduce, reuse, and recycle" are accepted principles of a CE, and the various R imperatives are the "how-to" of a CE and thus one of its core concepts (Kirchherr et al., 2017). The survey used in this study distinguishes five types of activities related to a CE: (i) redesigning the way water is used to minimize consumption and maximize re-usage, (ii) using renewable energy, (iii) redesigning energy usage to minimize consumption, (iv) minimizing waste by recycling, reusing, or selling it to another firm, and (v) redesigning products and services to minimize material use or use recycled material (European Commission, 2016).

We employ the logic used by Moric et al. (2020) to analyze the circularity activities in the firms, and we created the variable "CE adoption." They created four levels of CE adoption: (1) "non-adopters" – firms that have never planned to implement any activity related to the CE; (2) "planners" – firms that have not implemented any of the practices aligned with the CE, but are planning to do so; (3) "potential adopters" – firms that are in the process of implementing at least one of the types of activities aligned with the CE; and (4) "adopters" – firms that have adopted at least one of the types of activities related to the CE. We code the variable according to this logic: 1, 2, 3 and 4 – according to the classification.

3.2.2 *Exogenous variables*

Concerning the micro-level (or firm-level) variables, we previously discussed the influence of the firm's organizational strategy on the adoption of CE activities. We established the variable "R&D investments," which represents the percentage of a firm's turnover allocated to research and development (R&D) activities, as the "organizational strategy" variable, with higher levels indicating a strategic orientation towards differentiation (Yamakawa et al., 2011).

As a micro-level variable, to measure the financial capacity of the firm to implement CE projects, we also used the variable "financial capacity," which is a dummy for the necessity of access to financing (0) or not (1). Finally, to measure the firm's lack of technical skills, we created a dummy for the firms that declare a lack of human resources, lack of competence to implement a CE, or lack of knowledge about the benefits and necessary investments: if the firm presents some of these issues, then (1); if not, then (0).

Regarding the macro-level (or country-level) variables, economic performance was measured using the logarithm of the gross domestic product of each country in the year 2016: the variable name is defined as "GDP." For social performance, we used the Human Development Index (HDI) for the same year, by country. According to the United Nations Development Programme, the Human Development Index (HDI) is the geometric mean of normalized indexes of three dimensions: a long and healthy life, being knowledgeable, and having a decent standard of living. Finally, for environmental performance, we use the circular material use rate, defined as "CMU." The CMU rate is defined as the ratio of circular material use (U) to an indicator of the overall material use (M) (CMU=U/M): The indicator measures the share of material that is recovered and returned to the economy – avoiding the extraction of primary raw materials – in relation to the total material used (European Commission, 2020b). In summary, the circular material use rate evaluates the proportion of materials that are being kept in circulation and used within a closed-loop system, contributing to a more sustainable and efficient use of resources. The moderator variables were created using the product of the mean-centered first-order effect variables (Little et al., 2006).

$$CE * GDP = (CE\ adoption - mean\ of\ CE\ adoption) * (GDP - mean\ of\ GDP) \quad (1)$$

$$CE * HDI = (CE\ adoption - mean\ of\ CE\ adoption) * (HDI - mean\ of\ HDI) \quad (2)$$

$$CE * CMU = (CE\ adoption - mean\ of\ CE\ adoption) * (CMU - mean\ of\ CMU) \quad (3)$$

Finally, we used some control variables: (i) "age," which indicates the time frame in which the firm was established; (ii) "size," which represents the number of employees of the firm; (iii) "consumer type," which indicates whether a firm sells to firms (B2B), directly to customers (B2C), or both; and (iv) "sector," which distinguishes between four types of sector: manufacturing (NACE category C), retail, services, and industry (NACE categories B/D/E/F).

3.2.3 *Endogeneity test*

To tackle endogeneity issues, we employed an instrumental variable (IV) approach, which consists of a two-step logistic estimation method (2SLS) for our dependent variable. In the first step, our independent variable of interest is regressed on two instrumental variables: access to financing information and government incentives. The resulting adjusted probabilities are then used in the model. This approach is similar to the two-step least squares approach described by Bascle (2008), the most commonly used IV estimator.

4 Results

4.1 Sample characterization

Table 1 describes our sample of EU SMEs in terms of the number of employees, firm age, percentage of turnover invested in R&D, consumer type, sector, environmental management issues, and financial capacity. Most firms have less than 10 employees (61.6%), started their activities before 2010 (84.8%), belong to the retail (32.5%) and services (38.8%) sectors, and more than 75% invested less than 5% of their turnover in R&D in 2015. Regarding consumer type, we found that 42% of the firms are B2B, most of the companies (63.7%) did not mention environmental management issues, and they state that they do not require financing to implement environmental projects (54%).

As previously described, the "CE adoption" variable is divided into four categories. The "adopters" category represents 55.8% of the sample, meaning it accounts for more than half of the variable. As "CE adoption" is a central variable of the model, we understand that it would be important to add a more detailed description of its distribution. Tables 2 and 3 present a more detailed

Table 1
Sample characterization (N=4,550)

	Non-adopters	Planners	Potential adopters	Adopters	Total
CE adoption	18.5%	5.5%	20.2%	55.8%	100%
Number of employees					
1 to 9 employees	13.7%	3.7%	11.7%	32.4%	61.6%
10 to 49 employees	3.6%	1.3%	5.2%	14.2%	24.3%
50 to 250 employees	1.3%	0.5%	3.2%	9.0%	14.1%
Date firm established					
After Jan 1st 2015	0.3%	0.2%	0.3%	0.6%	1.3%
From Jan 1st 2010 to Jan 1st 2015	3.0%	0.8%	2.7%	7.3%	13.8%
Before Jan 1st 2010	15.3%	4.6%	17.1%	47.8%	84.8%
Sector					
Manufacturing (NACE category C)	1.4%	0.7%	3.2%	8.5%	14.0%
Retail	5.8%	1.6%	6.6%	18.4%	32.5%
Services	9.1%	2.2%	6.8%	20.6%	38.8%
Industry (NACE categories B/D/E/F)	2.2%	1.0%	3.5%	8.1%	14.8%
Consumer type					
B2C	3.5%	1.3%	3.2%	10.5%	18.5%
B2B	9.5%	2.1%	8.7%	21.7%	42.0%
Both	5.6%	2.2%	8.2%	23.5%	39.6%
Lack of technical skills					
Not mentioned	11.6%	2.1%	13.4%	36.6%	63.7%
Have some lack	6.9%	3.5%	6.7%	19.1%	36.3%
R&D investments					
Less than 5%	16.1%	4.3%	15.5%	43.2%	79.2%
From 5% to 9.9%	0.9%	0.4%	2.3%	5.3%	9.0%
From 10% to 14.9%	0.6%	0.4%	0.9%	3.2%	5.2%
From 15% to 19.9%	0.0%	0.1%	0.4%	1.4%	2.0%
20% or more	0.9%	0.2%	1.1%	2.5%	4.7%
Financial capacity					
Need for financing	12.7%	4.0%	8.1%	21.2%	46.0%
No need for financing	5.8%	1.6%	12.1%	34.6%	54.0%

description of the percentage of the types of activities adopted and also the amount of activities adopted by the firm.

We can see that the activity most implemented by companies is "minimizing waste by recycling, reusing, or selling it to another firm." This may be because these solutions are more mature and readily available, which makes it easier for companies to implement them. Most of the adopters implemented only one type of CE-related activity.

The following table shows the Pearson's correlations between all the variables of the model (Table 4). From an inferential perspective, we conclude that all SME characteristics (age, sector, consumer type and size) are statistically correlated with the CE adoption variable (p-value < 0.01), and that the factors R&D investments, environmental management issues and financial capacity are also correlated. The correlation between firm performance and CE adoption shows significance (p-value < 0.01). Among the moderating variables, only the moderation of environmental performance (CE*CMU) is not significant when correlated with firm performance. Nevertheless, it is necessary to test these relationships in the proposed model. To test the multicollinearity of the independent variables, we calculate the VIF: a very common cutoff reference corresponds to a VIF value of 10 (Hair Jr. et al., 2018). Our results show a low VIF for the control variables (age: 1.024; sector: 1.021; consumer type: 1.011; and size: 1.036), as well as for the independent variables (firm strategy: 1.011; technical skills: 1.011; financial capacity: 1.041; and CE adoption: 1.066). For the moderator variables, we identify a higher VIF value, but still lower than the cutoff value (CE*CMU: 1.218; CE*GDP: 7.271; and CE*HDI: 7.244).

Table 2
Number of activities

Number of activities adopted	% Activities
One type of CE-related activity	40.7%
Two types of CE-related activities	28.9%
Three types of CE-related activities	17.3%
Four types of CE-related activities	10.2%
Five types of CE-related activities	2.9%

4.2 Empirical model results

In line with our objective, the results on the relationship between CE and firm performance are presented in Figure 2 and the results of the hypotheses tests are presented in Table 5. The adjusted model shows suitable results: standardized root mean square residual (SRMR) = 0.067 (<0.08) and standardized root mean square error of approximation (RMSEA) = 0.0224 (<0.08). When we compare our model to a null model, the results are consistent: comparative fit index (CFI) = 0.986 (>0.95). The squared multiple correlations (R^2) for the dependent variable "firm performance" is 0.142 and for the explanatory variable "CE adoption" it is 0.127. R^2 values must be at least 0.10 for an endogenous construct to have its variance adequately explained (Falk & Miller, 1992). When we run the model using only the control variable, the R^2 for the dependent variable "firm performance" is 0.034 and

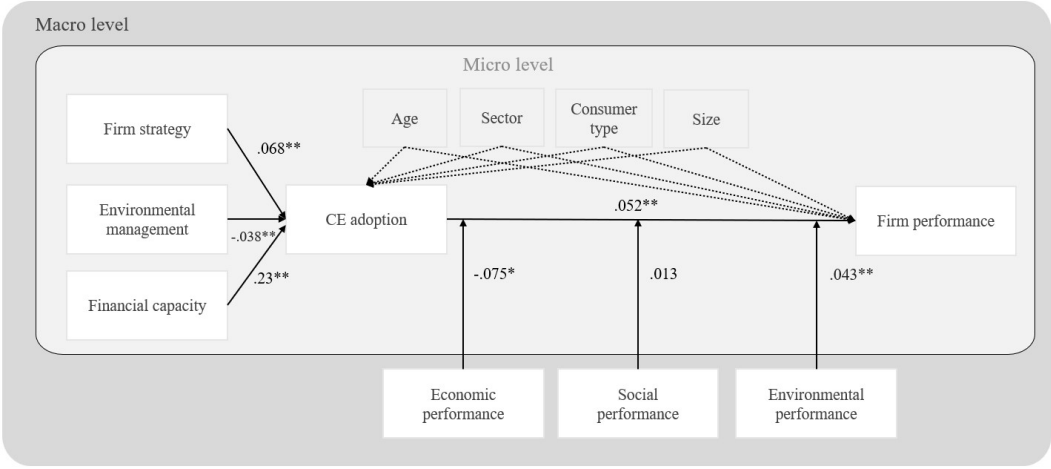

Figure 2. Empirical model results
**p < 0.01 (2-tailed); *p < 0.05 (2-tailed)

Table 3
Pearson's correlation matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Firm performance	1	0.109**	-0.027	-0.031*	-0.029	-0.070**	-0.061**	0.014	0.335**	0.316**	0.204**	0.082**	-0.057**	0.041**	-0.072**
2	CE adoption		1	0.056**	-0.054**	-0.237**	-0.066**	-0.046**	0.006	0.179**	0.145**	0.013	0.039**	-0.060**	0.060**	0.139**
3	R&D investments			1	0.054**	0.017	-0.035*	-0.039**	-0.011	-0.031*	-0.017	0.004	-0.036*	0.032*	0.020	-0.014
4	Lack of technical skills				1	0.148**	-0.027	-0.027	-0.014	-0.049**	-0.061**	-0.010	-0.010	0.017	0.034*	0.034*
5	Financial capacity					1	0.044**	0.049**	-0.002	-0.091**	-0.087**	0.010	0.005	-0.002	-0.045**	0.008
6	CE*GDP						1	0.928**	0.443**	-0.077**	-0.082**	-0.050**	0.043**	0.004	-0.038*	-0.013
7	CE*HDI							1	0.469**	-0.082**	-0.072**	-0.034*	0.046**	-0.003	-0.053**	-0.012
8	CE*CMU								1	-0.053**	-0.037*	0.144**	0.024	-0.018	0.007	0.016
9	GDP									1	0.917**	0.400**	-0.011	0.085**	0.037*	-0.067**
10	HDI										1	0.439**	-0.017	0.091**	0.047**	-0.065**
11	CMU											1	0.003	0.028	0.041**	-0.028
12	Age												1	-0.065**	0.001	0.198**
13	Sector														0.081**	-0.083**
14	Consumer type														1	0.049**
15	Size															1

**p < 0.01 (2-tailed); *p < 0.05 (2-tailed).

for the explanatory variable "CE adoption" it is 0.025, which supports the proposed model.

Table 2 shows that the empirical model supports most of the five hypotheses. The regression weight of Hypothesis 1 is 0.052 (p-value < 0.01), while those of Hypotheses 2a, 2b, and 2c are 0.068, -0.038, and 0.230, respectively (all with a p-value < 0.01). The test of Hypothesis 3a showed a negative effect (-0.075 with a p-value < 0.05) that was not expected and it was thus rejected. The test of Hypothesis 3b showed a regression weight of 0.013, but it does not show statistical significance for this model (p-value = 0.723). Hypothesis 3c was supported with a regression weight of 0.043 (p-value < 0.01). The control variable "age" also does not present statistical significance when associated with "CE adoption," even though it influences "firm performance." All other relationships presented statistical significance for inference analysis.

4.2.1 *Robustness test*

In order to understand whether a different approach to classifying the variable "CE adoption" would lead to different results in the model, we ran a robustness test with a new classification. In this new classification, "adopters" are divided into two new categories: (4) adopters of one type of activity and (5) adopters of two or more types of activities.

Table 4
Types of activities

Types of CE-related activities	% Adopters
(i) redesigning the way water is used to minimize usage and maximize re-usage	14.6%
(ii) using renewable energy	13.9%
(iii) redesigning energy usage to minimize consumption	29.6%
(iv) minimizing waste by recycling, reusing, or selling it to another firm	42.3%
(v) redesigning products and services to minimize the use of materials or use recycled material	23.2%

Table 5
Hypothesis test results

Relationship			Std Regression Weight	P	Hypothesis test
CE adoption	<---	Firm strategy	0.068	**	H2a supported
CE adoption	<---	Lack of technical skills	-0.038	**	H2b supported
CE adoption	<---	Financial capacity	0.230	**	H2c supported
CE adoption	<---	Age	0.010	0.493	-
CE adoption	<---	Sector	-0.066	**	-
CE adoption	<---	Consumer type	0.041	**	-
CE adoption	<---	Size	0.145	**	-
CE adoption	<---	Environmental performance	-0.048	**	-
CE adoption	<---	Economic performance	0.285	**	-
CE adoption	<---	Social performance	-0.092	**	-
Firm performance	<---	CE adoption	0.052	**	H1 supported
Firm performance	<---	Age	0.097	**	-
Firm performance	<---	Size	-0.087	**	-
Firm performance	<---	Consumer type	0.032	*	-
Firm performance	<---	Sector	-0.084	**	-
Firm performance	<---	Environmental performance	0.073	**	-
Firm performance	<---	Economic performance	0.274	**	-
Firm performance	<---	Social performance	0.024	0.496	-
Firm performance	<---	CE * Economic performance	-0.075	*	H3a rejected
Firm performance	<---	CE * Social performance	0.013	0.723	H3b rejected
Firm performance	<---	CE * Environmental performance	0.043	**	H3c supported

**p < 0.01 (2-tailed); *p < 0.05 (2-tailed).

The result of the tested model was similar to that of the original model: there was no difference in the hypotheses tested.

5 Discussion

The results are related to other studies and theoretical literature. Hypothesis 1 was also empirically confirmed by Zamfir et al. (2017), which was one of the few studies that explored the relationship between CE and firm performance. The study by Zamfir et al. (2017) showed that redesigning water usage, using renewable energy, minimizing material use, and minimizing waste are decisions that are beneficial to the environment and lead to improved economic performance.

Moric et al. (2020) showed in their research the influence of the stage of CE implementation on firm performance and found that adopters have higher productivity than potential adopters, who in turn are more productive than planners. Our study was able to add to their research by showing that firm performance is moderated by the influence of the country's environmental performance (Hypothesis 3c). The efficient use of resources reduces the dependence of the European economy on imports of raw materials (Ellen MacArthur Foundation, 2015; Rizos et al., 2016). With less dependence on foreign raw materials, the costs of production and management could be reduced, leading to an increase in productivity outcomes for firms. In addition, Kirchherr et al. (2018) infer that with higher raw material prices, circular products would be more affordable, which could stimulate the interest of consumers and increase firm results.

On the other hand, the high economic performance of a country negatively influences firm performance. According to Ellen MacArthur Foundation (2015), the implementation of CE activities could increase GDP and competitiveness. With our results (Hypothesis 3a), we can conclude that countries with a high GDP have a more intense competitive environment for firms, which may result in low profit margins for their products and services. The investments necessary to implement CE activities may put pressure on the costs of the implementing firm, thus affecting its productivity. The results of the country's social level (Hypothesis 3b) do not show statistical significance to infer its impact on productivity. Perhaps another proxy, such as consumer culture and lifestyle, could produce different results. Padilla-Rivera et al. (2021) proposed that consumer health and safety are the most relevant social CE indicators, based on the literature review and the ranking according to CE experts' value judgments. In addition to this fact, Kirchherr et al. (2018) found that some of the main barriers to a CE were lack of consumer interest and lack of awareness. This implies that countries with healthier and safer consumers have a higher environmental awareness.

Another contribution to the research is the result of Hypothesis 2a: firms with higher R&D investments, which indicates a strategic orientation of differentiation, tend to adopt CE activities more often than other firms, reinforcing the assumption that the implementation of circularity involves reorganizing the strategy and industrial process, and that firms with a differentiation strategy have more capacities for these changes. The technical skills are higher in firms with CE activities adoption, as stated in Hypothesis 2b: the higher the lack of technical skills, the lower the CE adoption. This indicates that the organization needs to invest in technical skills to implement circularity activities. Neubaum et al. (2004) found that CE adoption is negatively influenced by resource scarcity and survival concerns. This was confirmed in our results for Hypothesis 2c: firms with financial capacity implement a CE more often than other firms. This could be explained by the fact that SMEs often face difficulties in obtaining guarantees to secure the necessary funding from traditional banks (Dervojeda et al., 2014; Hyz, 2011; Rizos et al., 2016). Moreover, the study by Ghisetti and Montresor (2020) shows that self-financing is more important than debt financing for the implementation of CE activities. In turn, public financing is in the middle as a fundamental source, reinforcing the importance of direct government support for CE promotion.

When analyzing the influence of control variables, we found similar results compared to other studies: age does not show statistical significance in CE adoption. This result was also found by Hoogendoorn et al. (2015), who stated that age does not influence environmental practices. Sector, size, and consumer type influence CE adoption, which was also demonstrated by Zamfir et al. (2017).

Figure 3 and Figure 4 show the moderation effect. These results show a further step in CE research, especially when we evaluate the interaction between the levels of implementation (macro and micro). The economic and environmental development observed at the macro level can influence (positively or negatively) the results at the micro level (firm performance).

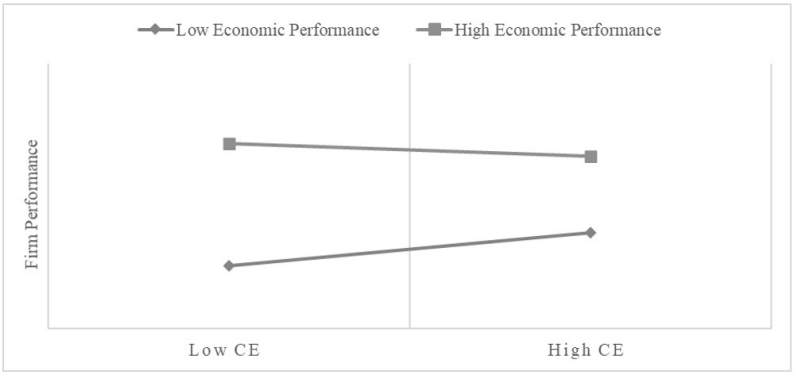

Figure 3. Economic performance moderation effect

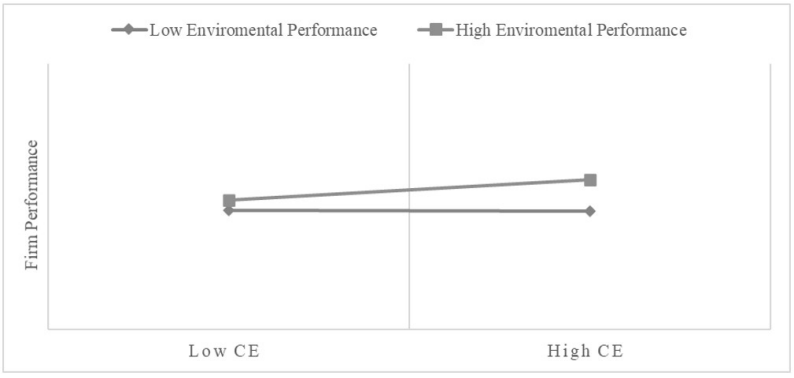

Figure 4. Environmental performance moderation effect

6 Conclusions

Studies on CE exploration have a predominance of qualitative research with a single case; however, as CE is a practice-oriented paradigm, the use of a quantitative methodology has become crucial for research articles in this field. This paper was able to develop CE assessment frameworks and metrics at the country, industry, and firm levels with a quantitative methodology. The paper examined the relationship between CE adoption and firm performance for SMEs, testing the influence of firm-level or micro-level factors and moderating this relationship with country-level (or macro-level) performance indexes. Applying an empirical model to a sample of 4,550 European SMEs, the results indicated that the country in which they operate may affect firm performance and influence companies' decisions to implement CE practices. A management approach to CE development should help understand the conditions for transforming a linear economy into a circular one.

By connecting the emergence of a CE to the national context, our study highlights the importance of considering macro-level factors when analyzing the impact of CE adoption on firm performance. The results support the view of some researchers that a CE must be proposed with an integrated approach across different levels of implementation. The need to move from a linear economic model to a more circular economic solution requires going beyond stimulating increased CE design and innovation efforts, in other words, it requires going beyond a micro-level analysis. It also requires increased investments in this field. Since enterprises are still one of the key players in this transition process, they must be more competent at meeting their needs by supporting relevant investment, infrastructure, technology, and skills plans, especially small and medium enterprises (European Commission., 2014). We emphasize that our results reveal that firm location directly influences the results of companies committed to adopting circularity activities. The country's environmental performance

could contribute positively to firm performance, but the contribution of its economic performance could be negative if the firm adopts more CE activities. Since a CE may perform differently depending on the location, copy-paste solutions will not be effective. Each firm and region should plan based on its own challenges.

Public direct investment policies, especially in countries with higher economic performance rates where firms operate at a higher level of competitiveness, can improve firm performance indicators and make CE adoption more attractive. Financial support for CE activities can be provided directly by the public sector or via other institutions (e.g., business associations and business development agencies), in different forms, such as grants, tax incentives, loans, or investment guarantees. In addition, countries that already operate with more current environmental legislation, with better environmental results, also help firm performance by stimulating a reduction in the cost of raw materials, which makes CE adoption more attractive due to the economic benefits generated. Therefore, some of the main reasons why European SMEs are proactively adopting the CE are the savings in material costs, the creation of competitive advantages, and the opening up of new markets.

The study has some limitations. For instance, the empirical model used did not include all possible exogenous variables, since it is difficult to represent the full diversity of indicators that influence the relationships. The use of secondary data also made this study challenging, as the development of the constructs depended on the available data, which required adaptations. Future research could use the empirical model presented in this study and implement other variables or use new constructs to understand the integration between levels of CE implementation, using other secondary data or surveys. In this study, we could not account for the influence of the social dimension on the results of firms. This should be addressed in future studies. Some authors have already proposed some indicators that could be more suitable for measuring circularity indexes that are not yet present in the European Commission reports, such as the Consumer Health and Safety Index.

REFERENCES

Aboulamer, A. (2018). Adopting a circular business model improves market equity value. *Thunderbird International Business Review*, *60*(5), 765-769. http://dx.doi.org/10.1002/tie.21922.

Amec. (2013). *The opportunities to business of improving resource efficiency.* European Commission.

Andersen, M. S. (2007). An introductory note on the environmental economics of the circular economy. *Sustainability Science*, *2*(1), 133-140. http://dx.doi.org/10.1007/s11625-006-0013-6.

Bačová, M., Böhme, K., Guitton, M., van Herwijnen, M., Kállay, T., Koutsomarkou, J., Magazzù, I., O'Loughlin, E., & Rok, A. (2016). *Pathways to a circular economy in cities and regions: A policy brief addressed to policy makers from European cities and regions.* European Commission. http://europa.eu/rapid/press-release_IP-15-6203_en.htm

Bascle, G. (2008). Controlling for endogeneity with instrumental variables in strategic management research. *Strategic Organization*, *6*(3), 285-327. http://dx.doi.org/10.1177/1476127008094339.

Bassi, F., & Dias, J. G. (2019). The use of circular economy practices in SMEs across the EU. *Resources, Conservation and Recycling*, *146*(April), 523-533. http://dx.doi.org/10.1016/j.resconrec.2019.03.019.

Bicket, M., Guilcher, S., Hestin, M., Hudson, C., Razzini, P., Tan, A., Ten Brink, P., Van Dijl, E., Vanner, R., & Watkins, E. (2014). *Scoping study to identify potential circular economy actions, priority sectors, material flows and value chains.* European Commission.

Bocken, N. M. P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308-320. http://dx.doi.org/10.1080/21681015.2016.1172124.

Calogirou, C. (2010). *SMEs and the environment in the European Union*. EU.

Cantú, A., Aguiñaga, E., & Scheel, C. (2021). Learning from failure and success: The challenges for circular economy implementation in SMEs in an emerging economy. *Sustainability*, *13*(3), 1529. http://dx.doi.org/10.3390/su13031529.

Chertow, M. R. (2000). Industrial ecology: Literature and taxonomy. *Industrial Symbiosis*, *25*, 313-337.

Coad, A., Segarra, A., & Teruel, M. (2016). Innovation and firm growth: Does firm age play a role? *Research Policy*, *45*(2), 387-400. http://dx.doi.org/10.1016/j.respol.2015.10.015.

Dalhammar, C. (2016). Industry attitudes towards ecodesign standards for improved resource efficiency. *Journal of Cleaner Production*, *123*, 155-166. http://dx.doi.org/10.1016/j.jclepro.2015.12.035.

Jesus, A., & Mendonça, S. (2018). Lost in transition? Drivers and barriers in the eco-innovation road to the circular economy. *Ecological Economics*, *145*, 75-89. http://dx.doi.org/10.1016/j.ecolecon.2017.08.001.

Delmas, M. A., & Pekovic, S. (2018). Organizational configurations for sustainability and employee productivity: A qualitative comparative analysis approach. *Business & Society*, *57*(1), 216-251. http://dx.doi.org/10.1177/0007650317703648.

Demirel, P., & Danisman, G. O. (2019). Eco-innovation and firm growth in the circular economy: Evidence from European small- and medium-sized enterprises. *Business Strategy and the Environment*, *28*(8), 1608-1618. http://dx.doi.org/10.1002/bse.2336.

Demirel, P., & Kesidou, E. (2019). Sustainability-oriented capabilities for eco-innovation: Meeting the regulatory, technology, and market demands. *Business Strategy and the Environment*, *28*(5), 847-857. http://dx.doi.org/10.1002/bse.2286.

Dervojeda, K., Verzijl, D., Rouwmaat, E., Probst, L., & Frideres, L. (2014). *Clean technologies, circular supply chains, business innovation observatory.* European Commission.

Doran, J., & Ryan, G. (2016). The importance of the diverse drivers and types of environmental innovation for firm performance. *Business Strategy and the Environment*, *25*(2), 102-119. http://dx.doi.org/10.1002/bse.1860.

European Academies Science Advisory Council – EASAC. (2016, November). *Indicators for a circular economy* (EASAC Policy Report, No. 30). EASAC.

Ellen MacArthur Foundation – EMF. (2015). *Towards a circular economy: Business rationale for an accelerated transition.* EMF.

European Commission. (2014). *Towards a circular economy: A zero waste programme for Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions.* European Commission. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014DC0398

European Commission. (2016). *Flash Eurobarometer 441. European SMEs and the Circular Economy.* European Commission. https://data.europa.eu/euodp/pt/data/dataset/S2110_441_ENG

European Commission. (2020a). *Entrepreneurship and Small and medium-sized enterprises (SMEs).* European Commission. https://ec.europa.eu/growth/smes_en

European Commission. (2020b). *EU circular economy action plan: A new circular economy action plan for a cleaner and more competitive Europe.* European Commission. https://ec.europa.eu/environment/circular-economy/

Falk, R. F., & Miller, N. B. (1992). *A primer for soft modeling.* Akron: University of Akron Press.

Feng, Z., & Yan, N. (2007). Putting a circular economy into practice in China. *Sustainability Science*, *2*(1), 95-101. http://dx.doi.org/10.1007/s11625-006-0018-1.

Friesenbichler, K., & Peneder, M. (2016). Innovation, competition and productivity. *Economics of Transition*, *24*(3), 535-580. http://dx.doi.org/10.1111/ecot.12100.

Garcés-Ayerbe, C., Rivera-Torres, P., Suárez-Perales, I., & Leyva-de la Hiz, D. (2019). Is it possible to change from a linear to a circular economy? An overview of opportunities and barriers for european small and medium-sized enterprise companies. *International Journal of Environmental Research and Public Health*, *16*(5), 851. http://dx.doi.org/10.3390/ijerph16050851. PMid:30857193.

García-Quevedo, J., Jové-Llopis, E., & Martínez-Ros, E. (2020). Barriers to the circular economy in European small and medium-sized firms. *Business Strategy and the Environment*, *29*(6), 2450-2464. http://dx.doi.org/10.1002/bse.2513.

Garson, G. D. (2013). *Path analysis.* Statistical Associates Publishing.

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The circular economy: A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757-768. http://dx.doi.org/10.1016/j.jclepro.2016.12.048.

Geng, Y., & Doberstein, B. (2008). Developing the circular economy in China: Challenges and opportunities for achieving "leapfrog development.". *International Journal of Sustainable Development and World Ecology*, *15*(3), 231-239. http://dx.doi.org/10.3843/SusDev.15.3:6. PMid:37309529.

Geng, Y., Fu, J., Sarkis, J., & Xue, B. (2012). Towards a national circular economy indicator system in China: An evaluation and critical analysis. *Journal of Cleaner Production*, *23*(1), 216-224. http://dx.doi.org/10.1016/j.jclepro.2011.07.005.

George, D. A. R., Lin, B. C., & Chen, Y. (2015). A circular economy model of economic growth. *Environmental Modelling & Software*, *73*, 60-63. http://dx.doi.org/10.1016/j.envsoft.2015.06.014.

Ghenţa, M., & Matei, A. (2018). SMEs and the circular economy: From policy to difficulties encountered during implementation. *Amfiteatru Economic*, *20*(48), 294-309. http://dx.doi.org/10.24818/EA/2018/48/294.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11-32. http://dx.doi.org/10.1016/j.jclepro.2015.09.007.

Ghisetti, C., Mancinelli, S., Mazzanti, M., & Zoli, M. (2017). Financial barriers and environmental innovations: Evidence from EU manufacturing firms. *Climate Policy*, *17*(Supl. 1), S131-S147. http://dx.doi.org/10.1080/14693062.2016.1242057.

Ghisetti, C., & Montresor, S. (2020). On the adoption of circular economy practices by small and medium-size enterprises (SMEs): Does "financing-as-usual" still matter? *Journal of Evolutionary Economics*, *30*(2), 559-586. http://dx.doi.org/10.1007/s00191-019-00651-w.

Hair Jr., J. F., Black, W. C., Babin, B. J., Anderson, R. E., Black, W. C., & Anderson, R. E. (2018). *Multivariate data analysis.* London: Wiley. http://dx.doi.org/10.1002/9781119409137.ch4.

Hansen, A. C., Thorn, P., Byskov, J., & Juul Jensen, J. (2014). *GREECO database report: GREECO-territorial potentials for a greener economy.* ESPON. http://www.espon.eu/export/sites/default/Documents/Projects/AppliedResearch/GREECO/DFR/GREECODFR_Volume-2_Scientific-Report.zip

Hollins, O. (2011). *The further benefits of business resource efficiency.* Department for Environment, Food and Rural Affairs. Final Report.

Hoogendoorn, B., Guerra, D., & van der Zwan, P. (2015). What drives environmental practices of SMEs? *Small Business Economics*, *44*(4), 759-781. http://dx.doi.org/10.1007/s11187-014-9618-9.

Hyz, A. B. (2011). Small and medium enterprises (SMEs) in Greece-Barriers in access to banking services: An empirical investigation. *International Journal of Business and Social Science*, *2*(2), 161-165.

Kalar, B., Primc, K., Erker, R. S., Dominko, M., & Ogorevc, M. (2021). Circular economy practices in innovative and conservative stages of a firm's evolution. *Resources, Conservation and Recycling*, *164*, 105112. http://dx.doi.org/10.1016/j.resconrec.2020.105112.

Khitous, F., Strozzi, F., Urbinati, A., & Alberti, F. (2020). A systematic literature network analysis of existing themes and emerging research trends in circular economy. *Sustainability*, *12*(4), 1633. http://dx.doi.org/10.3390/su12041633.

Kiefer, C. P., Del Río González, P., & Carrillo-Hermosilla, J. (2019). Drivers and barriers of eco-innovation types for sustainable transitions: A quantitative perspective. *Business Strategy and the Environment*, *28*(1), 155-172. http://dx.doi.org/10.1002/bse.2246.

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the circular economy: Evidence from the European Union (EU). *Ecological Economics*, *150*, 264-272. http://dx.doi.org/10.1016/j.ecolecon.2018.04.028.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*, 221-232. http://dx.doi.org/10.1016/j.resconrec.2017.09.005.

Koza, M. P., & Lewin, A. Y. (1998). The co-evolution of strategic alliances. *Organization Science*, *9*(3), 255-264. http://dx.doi.org/10.1287/orsc.9.3.255.

Li, C. (2020). Enhancing or inhibiting: The impact of investment in political ties on the link between firm innovation and productivity. *International Business Review*, *29*(2), 101636. http://dx.doi.org/10.1016/j.ibusrev.2019.101636.

Little, T. D., Bovaird, J. A., & Widaman, K. F. (2006). On the merits of orthogonalizing powered and product terms: Implications for modeling interactions among latent variables. *Structural Equation Modeling*, *13*(4), 497-519. http://dx.doi.org/10.1207/s15328007sem1304_1.

Liu, Y., & Bai, Y. (2014). An exploration of firms' awareness and behavior of developing circular economy: An empirical research in China. *Resources, Conservation and Recycling*, *87*, 145-152. http://dx.doi.org/10.1016/j.resconrec.2014.04.002.

Lüdeke-Freund, F., Gold, S., & Bocken, N. M. P. (2019). A review and typology of circular economy business model patterns. *Journal of Industrial Ecology*, *23*(1), 36-61. http://dx.doi.org/10.1111/jiec.12763.

Masi, D., Day, S., & Godsell, J. (2017). Supply chain configurations in the circular economy: A systematic literature review. *Sustainability*, *9*(9), 1602. http://dx.doi.org/10.3390/su9091602.

Merli, R., Preziosi, M., & Acampora, A. (2018). How do scholars approach the circular economy? A systematic literature review. *Journal of Cleaner Production*, *178*, 703-722. http://dx.doi.org/10.1016/j.jclepro.2017.12.112.

Moric, I., Jovanovic, J. Š., Dokovic, R., Pekovic, S., & Perovic, D. (2020). The effect of phases of the adoption of the circular economy on firm performance: Evidence from 28 EU countries. *Sustainability*, *12*(6), 2557. http://dx.doi.org/10.3390/su12062557.

Mura, M., Longo, M., & Zanni, S. (2020). Circular economy in Italian SMEs: A multi-method study. *Journal of Cleaner Production*, *245*, 118821. http://dx.doi.org/10.1016/j.jclepro.2019.118821.

Murillo-Luna, J. L., Garcés-Ayerbe, C., & Rivera-Torres, P. (2011). Barriers to the adoption of proactive environmental strategies. *Journal of Cleaner Production*, *19*(13), 1417-1425. http://dx.doi.org/10.1016/j.jclepro.2011.05.005.

Murray, A., Skene, K., & Haynes, K. (2017). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics*, *140*(3), 369-380. http://dx.doi.org/10.1007/s10551-015-2693-2.

Neubaum, D., Mitchell, M., & Schminke, M. (2004). Firm newness, entrepreneurial orientation, and ethical climate. *Journal of Business Ethics*, *52*(4), 335-347. http://dx.doi.org/10.1007/s10551-004-1532-7.

Ormazabal, M., Prieto-Sandoval, V., Puga-Leal, R., & Jaca, C. (2018). Circular Economy in Spanish SMEs: Challenges and opportunities. *Journal of Cleaner Production*, *185*, 157-167. http://dx.doi.org/10.1016/j.jclepro.2018.03.031.

Padilla-Rivera, A., do Carmo, B. B. T., Arcese, G., & Merveille, N. (2021). Social circular economy indicators: Selection through fuzzy delphi method. *Sustainable Production and Consumption*, *26*, 101-110. http://dx.doi.org/10.1016/j.spc.2020.09.015.

Porter, M. E. (1980). *Competitive strategy techniques for analyzing industries and competitors*. Free Press.

Rademaekers, K., Asaad, S. S. Z., & Berg, J. (2011). *Study on the competitiveness of the European companies and resource efficiency.* ECORYS.

Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The circular economy: New or Refurbished as CE 3.0? Exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. *Resources, Conservation and Recycling*, *135*, 246-264. http://dx.doi.org/10.1016/j.resconrec.2017.08.027.

Rizos, V., Behrens, A., van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., Flamos, A., Rinaldi, R.,

Papadelis, S., Hirschnitz-Garbers, M., & Topi, C. (2016). Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers. *Sustainability*, *8*(11), 1212. http://dx.doi.org/10.3390/su8111212.

Sakai, S., Yoshida, H., Hirai, Y., Asari, M., Takigami, H., Takahashi, S., Tomoda, K., Peeler, M. V., Wejchert, J., Schmid-Unterseh, T., Douvan, A. R., Hathaway, R., Hylander, L. D., Fischer, C., Oh, G. J., Jinhui, L., & Chi, N. K. (2011). International comparative study of 3R and waste management policy developments. *Journal of Material Cycles and Waste Management*, *13*(2), 86-102. http://dx.doi.org/10.1007/s10163-011-0009-x.

Scipioni, S., Russ, M., & Niccolini, F. (2021). From barriers to enablers: The role of organizational learning in transitioning SMEs into the circular economy. *Sustainability*, *13*(3), 1021. http://dx.doi.org/10.3390/su13031021.

Stahel, W. R. (2016). The circular economy. *Nature*, *531*(7595), 435-438. http://dx.doi.org/10.1038/531435a. PMid:27008952.

Stahel, W. R. (2019). *The circular economy: A user's guide.* Routledge. http://dx.doi.org/10.4324/9780429259203.

Su, B., Heshmati, A., Geng, Y., & Yu, X. (2013). A review of the circular economy in China: Moving from rhetoric to implementation. *Journal of Cleaner Production*, *42*, 215-227. http://dx.doi.org/10.1016/j.jclepro.2012.11.020.

Taranic, I., Behrens, A., & Topi, C. (2016). *Understanding the circular economy in Europe, from resource efficiency to sharing platforms: The CEPS framework* (Ceps Special Report, No. 143). Ceps.

Van Eijk, F. (2015). *Barriers & drivers towards a circular economy: Literature review.* (pp. 1-138). Naarden: Acceleratio.

Wautelet, T. (2016). *Circular economy as part of the corporate strategy: Competitive advantage or contemporary trend?* Luxembourg. http://dx.doi.org/10.13140/RG.2.2.18061.84963.

Wycherley, I. (1999). Greening supply chains: The case of the Body Shop International. *Business Strategy and the Environment*, *8*(2), 120-127. http://dx.doi.org/10.1002/(SICI)1099-0836(199903/04)8:2<120::AID-BSE188>3.0.CO;2-X.

Yamakawa, Y., Yang, H., & Lin, Z. (2011). Exploration versus exploitation in alliance portfolio: Performance implications of organizational, strategic, and environmental fit. *Research Policy*, *40*(2), 287-296. http://dx.doi.org/10.1016/j.respol.2010.10.006.

Zamfir, A. M., Mocanu, C., & Grigorescu, A. (2017). Circular economy and decision models among European SMEs. *Sustainability*, *9*(9), 1507. http://dx.doi.org/10.3390/su9091507.

SUPPLEMENTARY DATA

Supplementary material accompanies this paper.
Supplementary Data 1 – Description of variables and codes
Supplementary Data 2 – Database
Software: SPSS/Amos
Supplementary data for this article can be found online at https://doi.org/10.7910/DVN/ORVWH0, Harvard Dataverse, V1.

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