The use of circular economy practices in SMEs across the EU

Abstract

This study explores the circular economy (CE) practices of Small and Medium Enterprises (SMEs) in the 28 European Union (EU) member states. Five measures of CE are studied, namely Re-planning the way water is used to minimize usage and maximize re-usage, Using renewable energy, Re-planning energy usage to minimize consumption, Minimizing waste by recycling or reusing waste or selling it to another firm, and Redesigning products and services to minimize the use of materials or using recycled materials. Multilevel ordinal probit models that control within- and between-variability across European Union countries are estimated. Results show that CE measures across EU countries are very heterogeneous. At the firm level, we find that firm size (number of employees and total turnover in 2015) and percentage of firms' turnover invested in R&D in 2015 are significant in explaining within-country variations. The multilevel structure (between-country variability) accounts for 6.1% to 15.1% of the total variability of CE measures. These results have implications for the design of framework policies at EU level given that the firms surveyed are SMEs, the segment in which these CE measures most need improved planning and implementation.

Keywords: Circular economy, small and medium-sized enterprises (SMEs), cross-cultural research, multilevel modeling, European Union.

1 Introduction

The concept of the circular economy (CE) was introduced at the end of the last century; since the first scientific papers on the topic were published in the 1980s, it has received increasing attention from scholars (Lieder and Rashid, 2016). Although this vast literature offers many definitions of the circular economy, the key concept refers to harmonizing economic growth and environmental protection. A popular definition of the circular economy takes advantage of the easy-to-remember 3Rs: reduction, reusing, and recycling, and it describes the practical approach to the concept (see, for example, Liu et al., 2017). The Ellen MacArthur Foundation (2015) proposes a more comprehensive definition that includes environmental and economic advantages, according to which the circular economy is "an industrial economy that is restorative or regenerative by intention and design". This recent definition incorporates the idea of ensuring the safe entry of bio-nutrients in the biological sphere. Another important notion in this context is the difference between the circular economy and the linear production system: whereas the linear system perceives end-of-life products as waste, the circular economy sees them as resources, and this also has an impact on the environment, on resource scarcity, and on economic benefits. Other papers (e.g., Kopnina, 2018) underline the difference between CE and other paradigms of sustainability, like the quite popular cradle-to-cradle (C2C) developed by McDonough and Braungart (2002). As its name suggests, the aim of C2C is to return raw materials that have been taken from nature back to nature. C2C goes beyond the 3Rs principle by recognizing that although the 3Rs are a way of limiting environmental damage, they do not eliminate waste.

The circular economy was formally adopted in 2002 by the Central Government of China as a new development strategy to protect the environment and limit the production of pollution. This led to many scientific publications on both theoretical aspects of CE and its practical implementations for China and/or works authored by Chinese researchers. However, the roots of the topic are in Europe; the concept stems from the 1976 report to the European Commission by Stahel and Reday (1976), with another important contribution coming from the two British environmental economists Pearce and Turner (1990). Indeed, the concept has become increasingly accepted in the various regions of the developed world. In 2014, the European Commission (the body responsible for proposing new EU legislation) published its 2015 Circular Economy Package with the stated objective of "closing the loop" of product lifecycles (European Commission, 2014, 2015). In particular, the guidelines state that products should be redesigned so that they are easy to maintain, repair, remanufacture or recycle, which is another way of describing the 3R principle. Hughes (2017) provides an overview of this package. Forerunner countries such as Finland, the Netherlands, and the UK have adopted and applied national-level policies explicitly framed as circular (Repo et al., 2018). Stahel (2016) reports

that a study of seven European nations found that a shift to a circular economy would reduce each nation's greenhouse-gas emissions by up to 70% and grow its workforce by about 4% — the ultimate low-carbon economy. Nevertheless, implementing the circular economy is a challenging task given the prevalence of a linear mindset in industry and society. According to various researchers, it is easier to see environmental benefits than economic benefits. Implementing circular economy practices often entails industries making extra investments that might not be considered profitable (Dalhammar, 2016). It is generally believed that policy initiatives favoring the circular economy are required worldwide. In Europe, the current rules do little to foster this market development (Dalhammar, 2016).

It is recognized that the choices of firms and people on production and consumption styles are all vital for sustainable development and consumers also need to embrace CE. As a result, many papers have analyzed the profiles of the so-called green consumers and their behavior regarding household waste reduction, reuse, recycling, green purchasing and focusing on different parts of the world: UK (McDonald and Oates, 2003), Sweden (Jansson et al., 2010), Japan (Hanyu et al., 2000), and China (Huang et al., 2006). On the other hand, published research on firms addresses specific economic sectors (e.g. Ge and Jackson (2014) refer to the automotive sector) or geographical areas (e.g. Dalhammar (2016) for Scandinavia). The circular economy has developed mainly in big industries and has not spread sufficiently to SMEs (Ormazabal et al., 2018).

Small and medium-sized enterprises (SMEs) represent 99% of all businesses in the EU[1] varying from 99.5% (Germany and Luxembourg) to 99.9% (France)[2]. Between 2002 and 2010, the SMEs in EU had a much higher employment growth rate (1% annually) than the large enterprises (0.5%)[3]; and in recent years, they have created most of the new jobs. Not only are they a very big group, but they also contribute to a large share of the overall pollution (ECEI, 2010). Nevertheless, specific research on CE practices in the SME segment is scarce. This paper focuses on the use of circular economy practices in the European Union (EU) by SMEs; specifically, it analyzes the activities of European SMEs with regard to the circular economy. The European Union funds many projects fostering CE practices in SMEs (https://www.clustercollaboration.eu/). Some recent literature focuses in particular on the topic of barriers and enablers of implementing the circular economy by small and medium-size firms (see, for example, Rizos et al., 2016).

[1] Small and medium-sized enterprises (SMEs) are defined in the EU recommendation 2003/361 (http://data.europa.eu/eli/reco/2003/361/oj). It means less than 250 employees, or ≤50m€ turnover, or ≤ 43m€ balance sheet total.

[2] Eurostat (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_sc_sca_r2&lang=en) (accessed on 26.08.2018).

[3] Eurostat (http://europa.eu/rapid/press-release_MEMO-12-11_en.htm?locale=en) (accessed on 26.08.2018).

Schaltegger and Wagner (2011) studies the conditions under which sustainability innovation emerges spontaneously in companies. They identify, for example, industry life cycle as a crucial factor. del Rio Gonzàles (2005) identifies factors external and internal to the firm that stimulate the adoption and diffusion of clean technology; while external factors relate mainly to regulations, internal factors involve employees, organizational culture, brand image and reputation, competitive advantage and strategic intent, and environmental management capacities. It is important to understand that SMEs are not smaller versions of their larger counterparts (Welsh and White, 1981). Most of these internal conditions are influenced by a more difficult separation between decision making and management and the ownership of the capital. Firm size is particularly relevant as medium-sized organizations, both in terms of the number of employees and turnover, are more engaged in CE practices (Hoogendoorn et al., 2015). Another important factor is the type of market being served. Hoogendoorn et al. (2015) show that SMEs selling directly to consumers are just as likely to engage in greening processes as those selling to other companies. Finally, the firm's age has also been researched as an influencer of the firm's engagement in CE practices. Neubaum et al. (2004) conclude that scarcity of resources and concern about survival may have a negative influence, whereas Hockerts and Wüstenhagen (2010) show the opposite relation. On the other hand, Hoogendoorn et al. (2015) found that age did not have any influence on environmental practices.

This research aims to assess the firm factors that can influence CE practices in all sectors of the EU's SMEs. We study specific dimensions of CE activities: energy efficiency, waste of water, and the use of recycled materials. Based on previous studies, we expect that the level of tangibility of the industry and the type of market, i.e., whether the firm sells services or goods to either consumers or companies, and R&D spending have a positive impact on the implementation of CE practices. The age of the firm is not expected a priori to have a role in the implementation of CE practices. Descriptive statistics show that although circular economy practices are adopted by firms in all 28 European countries, there are differences both within countries due to firms' characteristics – dimension, age, turnover, type of activity – and between countries: environmental and energy-saving practices are not given the same attention everywhere in Europe. Thus, there is a hierarchical structure in the population of SMEs in the EU, i.e., firms are nested within European countries; as a result, we will consider heterogeneity between different types of firm and between different countries. This research draws on information about SMEs operating in all economic sectors in all 28 European Union countries, collected in Eurobarometer surveys. The estimation of multilevel ordinal probit regression models investigates the possible determinants of the adoption of practices at the firm level and also evaluates the effect of differences between countries.

The paper is organized as follows. Section 2 describes data and methods (multilevel analysis). Section 3 reports the results of model estimation with reference to our sample of European firms. Section 4 concludes and provides lines for future research.

2 Methods

2.1 Eurobarometer data set

This research uses data from the Flash Eurobarometer 441 (European SMEs and the circular economy) conducted in the 28 EU Member States[4] in April 2016 and involves 10,618 interviews under the supervision of the European Commission (European Commission, 2016).[5] This is a unique and representative sample of EU firms selected by multi-stage random sampling that allows a comparative study of different countries as data is collected using a common methodology. Firms employing from 1 to 250 persons within manufacturing, retail, and services are the respondent units. Questions are about circular economy-related activities in the last three years and characteristics of the firms. The questionnaire is translated into the native language of the interviewee and back-translated to ensure the quality of the questionnaire. The European weights, reproducing the actual "number of cases for each country", ponder the sample size with the universe size (derived from EUROSTAT population data or from other national statistics institutions) to obtain a stratified sample, and were applied to the data set. This methodological care enhances the usefulness of this secondary data for scientific research, even though contents are constrained and selected based on policy-oriented priorities of the European Commission.

2.2 The multilevel model

The data at our disposal are hierarchical, i.e., SMEs are nested into countries; this structure requires appropriate models to be used for the analysis, something that has not been previously done in the literature (e.g., Hoogendoorn et al., 2015). The study applies a multilevel ordinal probit regression model to be estimated simultaneously at two levels: the individual level measures the impact that the characteristics of the firms in each country have on their CE intentions and behaviors; the country level highlights the similarities (or differences) between EU countries. As firms from the

[4] The 28 EU countries in this analysis are listed in Table 2.

[5] The Eurobarometer surveys examine European opinion and behavior on many distinct topics ranging from the support for developing countries and opinions on EU policy to the implementation of new technology. Data can be accessed from: www.gesis.org/eurobarometer-data-service/search-data-access/data-access

same country share a set of characteristics, the traditional assumption of independence is violated. Such a nested structure is taken into account by the multilevel modeling, making it a particularly suitable model to apply in our analysis (Hedeker and Gibbons, 1994; Hox, 2002; Snijders and Bosker, 2012). For example, estimating an ordinary linear regression model on hierarchical data is not correct since (i) residuals may not be assumed independent and (ii) it is not possible to disentangle variability at the various levels (Snijders and Bosker, 2012). The value y_{ijk} measures the response of individual i (SME i) from country j on the item k regarding CE intentions on an ordinal scale. Ordinal data is modeled by assuming an underlying continuous latent variable, y^*_{ijk}, that measures the propensity of individual i in country j to choose category m and is related with the ordinal item by thresholds:

$$y_{ijk} = m, \text{ if } \tau_{k,m-1} < y^*_{ijk} < \tau_{k,m} \quad (1)$$

where $\tau_{k,m}$ is the threshold for item k that defines the categories $\mathrm{m} = 0, \ldots, \mathrm{M}$, with $\tau_{k,0} = -\infty$ and $\tau_{k,M} = \infty$. Thus, higher values of y^*_{ijk} indicate higher categories of the observed ordinal variable. For an *M*-level ordinal variable, $M - 1$ thresholds are required. The ordinal variables are explained by a set of P observed covariates (x_{ijp}). The linear component of the model is given by $y^*_{ijk} = \boldsymbol{\beta}\boldsymbol{x}'_{ij} + u_j + \epsilon_{ij}$, where $\boldsymbol{x}_{ij}$ is the vector that contains the observed covariates for observation i in cluster/country j, $\boldsymbol{\beta}$ is the vector of regression parameters (fixed effects), u_j is the random effect for cluster/country j, and ϵ_{ij} is the error term. The thresholds replace the intercept in the model, whereas the random effect (u_j) represents factors affecting y^*_{ijk} that are shared by all units within cluster/country j, after controlling individual covariates. The multilevel ordinal probit regression model assumes standard normal errors and that random intercepts (u_j) are independent of the errors (ϵ_{ij}) and normally distributed: $u_j \sim N(0, \sigma_u^2)$. The intra-class correlation coefficient (ICC) is the proportion of the total dispersion that is explained by the country level: $ICC = \sigma_u^2/(1 + \sigma_u^2)$. Descriptive statistics and chi-square tests are used to describe the data and test independence between non-metric variables, respectively. In hypothesis testing, the maximum probability of type I error (level of significance) is set at 0.05.

2.3 Variables

Two sets of variables are selected from the Eurobarometer sample: implementation (behavior and intentions) of the CE activities in the 28 European Union by SMEs and profiling variables.

The questionnaire does not provide a definition of CE, but the respondents are asked to report on the adoption in the last three years of five CE activities: re-planning the way in which water is used to minimize usage and maximize re-usage, using renewable energy, re-planning energy usage to minimize consumption, minimizing waste by recycling or reusing waste or selling it to another firm, and redesigning products and services to minimize the use of materials or using recycled materials. These five CE activities refer to energy efficiency, waste of water, and use of recycled materials that are among the EU policy objectives for environmental issues; they refer specifically to the category of making products more efficient (European Commission, 2003). The scale of measurement defines a spectrum from no intention to adopt in the near future to an observed behavior, using the ordinal categories: 1 - "No, and we do not plan to do so", 2 - "No, but we plan to do so", 3 - "Yes, activities are underway", and 4 - "Yes, activities have been implemented". These answers generate ordinal response variables for the multilevel probit regression models. In all models, a random effect at the country level is specified in order to account for differences across countries.

The independent variables characterizing the firms are the number of employees (full-time equivalent), the date when the firm was established, firm's total turnover in 2015, type of products/services being sold, and percentage of firm's turnover invested in R&D in 2015. The categories of these variables are depicted in Table 1. As the firm's size is measured using two different indicators, namely the number of employees and total turnover, the association between the two variables was analyzed to avoid problems of multicollinearity in the regression models. Kendall's tau-c correlation, which varies between -1 and 1, confirms that the association between the two ordinal variables (0.12) is weak (unweighted sample).

Six multilevel probit models are estimated as follows: first, a binary dependent variable, which assumes a value of 1 if the firm undertook at least one CE activity in the past three years (the dependent variable assumes the value 0, if the firm did not undertake any of the five CE activities)[6]; then, five ordinal probit regression models which refer to each specific CE activity proposed in the questionnaire using the ordinal scale defined above.

[6] The binary probit regression model is an ordinal probit regression model with a single threshold between the two levels.

3. Results

3.1 Sample characterization

Table 1 reports the characterization of the sample of SMEs with reference to the number of employees, the age of the firm, the total turnover in 2015, the percentage invested in research and development (R&D), and the types of products or services being sold. Most of the SMEs have less than 10 employees (92.7%), were founded before 2010 (80.5%), more than 95% of SMEs had a total turnover of up to 10 million euros in 2015, more than 75% of them invested less than 5% of firm's turnover in R&D in 2015. Regarding the tangibility and type of market, we find that 43.2% of firms sell products directly to consumers, 36.1% sell products to companies or other organizations, 43.4% sell services directly to consumers, and 50.9% sell services to companies or other organizations. From an inferential perspective, we conclude that all SME characteristics, except age, are statistically associated with the binary variable indicating whether or not the firm undertook some CE practice (the chi-square test shows a p-value <0.001). The decision to undertake activities recommended by the European Union is significantly associated with the number of employees: larger firms are more prone to circular economy policies. Circular economy practices are used slightly less in firms that provide services. The type of client and all types of products/services being sold except services to organizations are significant. In this latter case, there is no difference between adopting and not adopting circular economy-related activities in the past three years. Finally, there is a significant direct association between investing a larger percentage of the turnover in research and development and the implementation of circular economy-related activities in the past three years.

[Table 1 about here.]

Table 2 summarizes the sample at the country level, i.e., it provides insights into the variability between countries in terms of firms' size and products vs. services sold. These figures are comparable since statistics are calculated with weighted data that account for the differences in the number of firms in various countries. There is an almost negligible difference in the distribution of firms by the number of employees; however, Ireland has the largest proportion of big firms, Germany has the highest percentage of firms with between 10 and 49 employees, and Greece has the highest proportion of small firms. The data on the distribution of firms by type of activity shows greater heterogeneity.

[Table 2 about here.]

Additional information is provided on the percentage of firms in each category that undertook any circular economy related activity in the past three years. Of the 10,618 interviewed firms, 73.2% undertook at least one of the five above-mentioned green actions in the last three years.

Table 3 reports figures on the adoption of circular economy practices at the country level. Countries are ranked in descending order for the percentage of the sampled firms' adoption of at least one circular economy practice in the last three years. The most virtuous country is Malta, where over 90% of SMEs have undertaken at least one of these five CE following activities. The lowest percentage (43.8%) is observed in Bulgaria; there is a non-negligible heterogeneity in the percentages referring to all 28 EU countries. Less heterogeneity appears in the percentage of total turnover devoted by firms to research and development in 2015.

[Table 3 about here.]

Figure 1 depicts the information contained in Table 3. The EU-28 countries are positioned on the two-dimensional graph, showing the percentage of SMEs that undertook at least one circular economy activity in the past three years (horizontal axis) and the percentage of SMEs that invested more than 20% of the turnover in 2015 in research and development (vertical axis). Neighboring points in the graph represent countries with similar behavior. Malta has an interesting profile: although it has the highest percentage of firms that apply CE policies, very limited resources are devoted to research and development. The behavior of Romania is also unusual: it has the highest percentage of firms investing more than 20% of turnover in R&D, but only slightly more than 60% of them adopt CE policies. Countries can be classified into four homogeneous groups (not considering Malta and Romania). The first group is formed by Estonia, Bulgaria, Lithuania, Latvia, and Hungary. In these countries, CE activities are not diffused and investment in R&D is low. The group composed of the United Kingdom, Luxemburg, Austria, Belgium, Estonia, Portugal, Spain, and Ireland is characterized by firms that are very receptive to good ecological practices. A third very small group is formed by France and Hungary, where investment in R&D is especially low. Finally, the fourth and biggest group containing all other EU countries has an average profile for both the surveyed behaviors.

[Figure 1 about here.]

3.2 Overall circular economy-related activity

The figures in Table 4 show which factors have a statistically significant effect on the probability of a firm adopting at least one suggested action. Firm's age has no significant effect. Firm's size, total turnover, and percentage invested in R&D have a significant positive effect; as the firm's size increases in terms of employees and/or turnover, the probability of adopting at least one CE activity rises. Type of activity, which combines tangibility of the industry (product vs service) and type of market (business to business vs business to consumers), generally has a positive effect but with a different magnitude across categories; firms selling services directly to consumers are the most prone to CE. Because the variance of the random effect is positive ($p<0.05$), there is heterogeneity in this behavior between countries. The intra-class correlation coefficient (ICC) is 0.114, i.e., the country level accounts for 11.4% of the variability. This result confirms the evidence reported in Figure 1 and Tables 2 and 3.

[Table 4 about here.]

Figures 2, 3, 4, 5, and 6 represent the percentage of responses to the question on the adoption of the five CE practices by country. The profiles of each country in the five figures are quite distinct, indicating that behavior is different. Below, we will analyze the adoption of each practice, commenting on both the relative figure and the results of the multilevel ordinal probit regression model reported in Table 5.

3.3 Re-planning the way water is used to minimize usage and maximize re-usage

Re-planning water usage falls into the category of environmental policies aimed at making products more energy efficient. Moreover, the environment also benefits from less resource depletion. With reference to the entire sample, an average of 18.8% of firms in Europe implemented this action in the past three years or have some activities underway, 7.1% plan to do so, 69.6% of firms neither perform this activity nor plan to do so in the future. However, as can be seen from Figure 2, the situation differs greatly across countries. The percentage of adoption in the most virtuous countries – Ireland, Luxemburg, and Portugal – is over 30%; a second group has an above average percentage (Belgium, Spain, Finland, France, and Great Britain); all the other countries are below the average.

[Figure 2 about here.]

Model estimates in Table 5 show that firms' age does not have a significant effect. The number of employees has a significant and positive impact on the probability of undertaking this policy; the

297 effect increases with size. Total turnover has a positive significant effect only for firms with a
298 turnover of more than 10 million Euros. Selling products or services directly to consumers has a
299 significant positive effect on the behavior under analysis. Finally, the higher the percentage of total
300 turnover invested in R&D, the more likely the firm is to adopt CE activities. As noted previously,
301 heterogeneity across countries cannot be neglected (positive variance of the random effect) and the
302 ICC is 10.4%.

303 [Table 5 about here.]

304

305 **3.4 Use of renewable energy**

306 The European Community Directive on renewable energy (European Community, 2009) requires that
307 at least 20% of Europe's total energy needs are met with renewables by 2020. As can be seen from
308 our data, only 15.8% of firms had adopted this CE framework in 2015 or were in the process of doing
309 so, and 67.1% do not plan to comply in the near future. Moreover, heterogeneity across countries is
310 non-negligible in this case (Figure 3); Austria has the highest percentage of firms using renewable
311 energy and Poland the lowest. The group of virtuous countries with over 30% of firms using
312 renewable energy is quite different from that of the previous policy and is made up of Austria,
313 Germany, and Luxemburg. Belgium, the Netherlands, Finland, France, Great Britain, Ireland, Malta,
314 Sweden, and Slovenia are above the average.

315 [Figure 3 about here.]

316 The results of the estimation of the ordinal regression model (Table 5) are very similar to those
317 described in the previous paragraph, except for the negative effect of firms founded in the last year;
318 in this case, younger firms are less prone to adoption, and the effect is also non-significant for firms
319 that sell products directly to consumers. The country level accounts for 8.5% (ICC). With regards to
320 total turnover, it has a negative effect on the adoption of this policy when it is very low, below
321 50,000 Euros, but a positive effect when very high, over 10 million.

322

323 **3.5 Re-planning energy usage to minimize consumption**

324 In the last 50 years, the consumption of energy by the industrial sector has more than doubled and
325 its cost has increased; moreover, the majority of sources are non-renewable and the environmental
326 impacts are therefore significant. Minimizing energy consumption is a very important goal at EU

level. Energy consumption can be reduced through more energy-efficient production processes; these include energy efficient particle size reduction and the efficient use of raw materials (Garetti and Taisch, 2011). Our survey analysis does not investigate the specific actions undertaken by firms to minimize energy consumption and they may vary in line with various firm characteristics. However, it detects that 37.7% of European SMEs undertook or are undertaking some measures. This is the most adopted green action as it has the strongest direct link to cost reduction. It is adopted by over 50% of firms in several countries (Finland, Ireland, and Malta) and by below or around 20% in few countries, most of which are in Eastern Europe (Bulgaria, Estonia, and Lithuania) (Figure 4).

[Figure 4 about here.]

The determinants for adopting this policy are given in Table 5: size - the bigger the firm, the larger the positive effect; total turnover - a positive effect is detected after 500,000 Euros; the type of production - significant positive effect for goods and services sold directly to consumers; percentage of turnover devoted to R&D - increasing positive effect. We conclude that the heterogeneity at the country level explains 6.5% of the dispersion in the model.

3.6 Minimizing waste by recycling or reusing waste or selling it to another company

Waste disposable, separation and reuse has emerged as a crucial issue in the EU and it is frequently referenced in EU documents (see, for example, European Commission, 2012). For example, the EU planned measures to increase waste reuse offer a range of environmental, economic, and social benefits. This option, however, has only been developed to a limited extent in the EU, as our data demonstrate; in fact, our analyses show that only 55.4% of EU firms have adopted or are about to adopt this policy. The most virtuous group of countries is composed of the United Kingdom, Ireland, and Malta (Figure 5).

[Figure 5 about here.]

Table 5 reports the inferential results. The likelihood of undertaking this activity increases with the firms' size (number of employees and total turnover), and the percentage of turnover devoted to R&D. Type of activity is also significant, which means that both the tangibility of the product and the type of clients are important. Firm's age is not significant. Water reuse is the item with the biggest country-level effect (ICC=0.151).

3.7 Redesigning products and services to minimize the use of materials or using recycled materials

A sustainable design approach for new products/services with a much better environmental performance is a key element to achieve sustainability. By the end of 2015, 34.4% of EU firms undertook or were undertaking these practices. The leading countries are Luxemburg and Malta (Figure 6).

[Figure 6 about here.]

The positive determinants of this behavior according to the model estimation are firm's size, turnover over 500,000 Euros, type of activity, investment in R&D, and age, since there is a significant positive effect for the oldest SMEs (Table 5). This CE strategy has the smallest country-level impact (ICC=0.061).

4 Discussion and conclusion

Despite the growing number of European Union policies on environmental issues, these policies are only adopted by a small proportion of firms and notably small and medium enterprises. This study focuses on SMEs as most of the research about the circular economy has examined big industries. This article provides an overview of the five CE activities which SMEs in the European Union practice or intend to implement. More specifically, it shows the variability of practices across countries and examines the SME conditions that influence this adoption.

The paper analyzes survey data collected by the European Commission within the Eurobarometer framework. This specific survey dates from April 2016 and the sample is made up of over 10,000 SMEs distributed across all 28 EU countries. The sample is composed of firms of different sizes, ages, and types of activity to ensure it is representative of the entire population. As a result, this research extends previous knowledge, which concentrated either on limited geographical areas or specific economic activities. The survey data allows us to explore the spread of CE practices in SMEs across EU member states and to evaluate the determinants of this behavior.

We found that 73.2% of the firms undertook or were in the process of undertaking at least one CE activity in the past three years; however, the situation varies greatly across countries. At the firm level, the determinants of green behavior are size, total turnover, percentage of turnover devoted to R&D, and type of activity. Other potential covariates, such as age, were not found to be statistically significant.

Minimizing waste by recycling or reusing waste or selling it to another company is the CE practice adopted most by SMEs (55.4% of firms have adopted or are about to adopt this policy), followed by re-planning energy usage to minimize consumption (37.7% of SMEs) and redesigning products and services to minimize the use of materials or using recycled material (34.4%). This last practice goes beyond efficiency as it involves a fundamental reassessment of the use of resources; thus, the fact that a very high percentage of firms do not intend to implement it in almost all 28 EU countries is a striking result. The use of renewable energy was adopted or considered for the immediate future by only 15% of firms, making it the CE practice with the lowest percentage. However, re-planning the way water is used to minimize usage and maximize re-usage had only a slightly higher percentage (18.8%).

The five practices also differ in relation to the firm characteristics with a significant effect on their adoption. Notwithstanding, the firm's size and the percentage of total turnover devoted to R&D have a statistically significant effect in all models, indicating that these two elements may become crucial factors in the development of green actions. The practices of redesigning products and services and minimizing waste by recycling are also determined by resources since there is a positive effect on the probability of their adoption only for firms with a total turnover greater than 500,000 Euros.

This result indirectly indicates that enterprises with few resources may be able to afford practices such as reduction of waste but not more demanding redesigning practices. This evidence casts some doubts on the equation between CE and efficiency; whereas efficiency simply means to produce more value with less input, CE practices imply a new way of thinking, that is, not only reducing inputs or waste but, as C2C suggests, returning raw materials to the environment.

Other interesting evidence emerges through an analysis of the variability in the adoption of CE practices across the 28 EU member states. The ICC figures estimated with the multilevel ordinal regression models show that redesigning products and services has the lowest level of variability; in other words, in SMEs across all countries in the EU, redesigning products and services is not among the first practices adopted but, in addition to this, there are no plans to adopt this strategy. Only Portugal, France, Great Britain, Luxembourg, and Ireland have over 30% of firms already implementing this action. On the other hand, the percentage for Eastern European countries and Italy is almost negligible. The implementation is underway in more than 20% of firms in Estonia, Czech Republic, Luxembourg, Spain, and Slovenia. Minimizing waste is the practice with the greatest variability across countries because, although it has an average implementation by SMEs, almost no firms adopt it in a small group of countries, namely in Bulgaria and Estonia. It is a concern that EU

SMEs have no plans to adopt redesigning practices as this was one of the main approaches of the EU circular economy package.

The case of Malta is interesting as the small country has the highest percentage of SMEs that undertook at least one CE related activity. However, in 2016, the municipal waste recycling rate (including composting) reported by Malta to Eurostat was 7 %[7], which means that Malta is one of the 14 European countries lagging behind the 2020 target of 50% preparation for re-use/recycling of municipal waste; this result shows the need for more country-specific and detailed studies as it seems there may be very different situations within countries (according to the Eurobarometer data, the Maltese SMEs were the most proactive in the EU).

Evidence emerging from our analyses suggests a number of lines of future research, both within specific countries, as in the example of Malta, and also between countries with different characteristics or belonging to different regions of the EU. For example, our models could include covariates collected at county level, such as indicators of economic and social wealth that are available in official statistics and are disseminated by National Statistical Institutes and Eurostat. This type of analysis could also help explain why certain practices are seldom adopted in some geographical areas, while others are lacking across almost all EU member states. Whereas the former should be promoted with country specific policies, EU policy orientation should be redefined for the latter with new incentives for all EU state members. Moreover, it would be fruitful to extend some recent studies on the internal and external drivers favouring the adoption of CE practices (e.g. Yadav et al., 2018) by analysing these in conjunction with firms' conditions. The Eurobarometer surveys collect regular information on CE practices; thus, further analyses would allow our findings to be compared with others using future data. For example, information obtained from the two-yearly Eurobarometer survey on resources efficiency and green markets in SMEs in Europe could be used to explain some of the results obtained in our research. A future stream of research might also compare SMEs with large companies using a representative sample of all EU firms. Such a sample could shed light on the scale factors that would allow the five CE activities to be implemented.

Green competences in European SMEs are an additional topic of interest, namely, finding out how many workers perform green jobs and the importance of these skills in the eyes of managers. The relationship between CE practices, employment, and green skills has recently found space in the reference literature (see, for example, Ghisellini et al. 2016) and seems a promising field to be explored to explain the adoption of CE practices at firm and country levels. This is the case of SMEs in particular as the segment is usually described as lagging behind in terms of CE. However, the

[7] http://ec.europa.eu/environment/waste/pdf/early_warning_report_MT.pdf (accessed on 26.08.2018).

failure to act may be due to insufficient resources and expertise rather than a lack of positive attitudes towards green practices (Cassells and Lewis, 2011).

In conclusion, more research is needed to disseminate this knowledge and develop this new way of thinking in SMEs. Not only do these results generate novel ideas for future research but they also provide EU policymakers with indications of key priorities and the information required.

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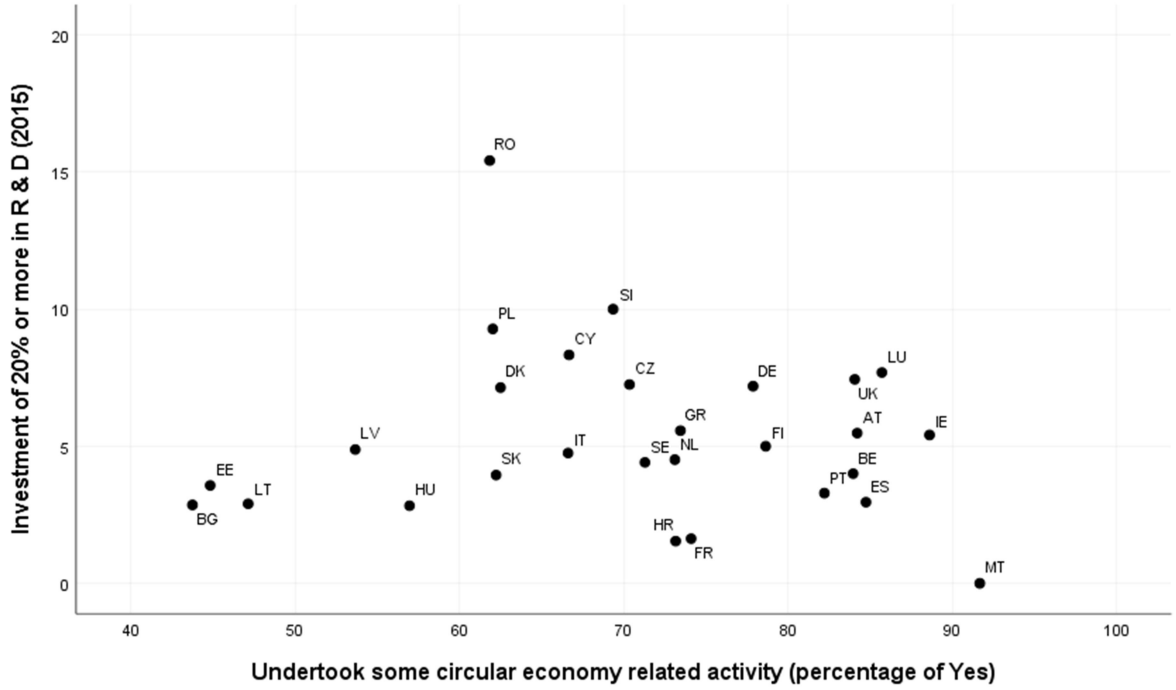
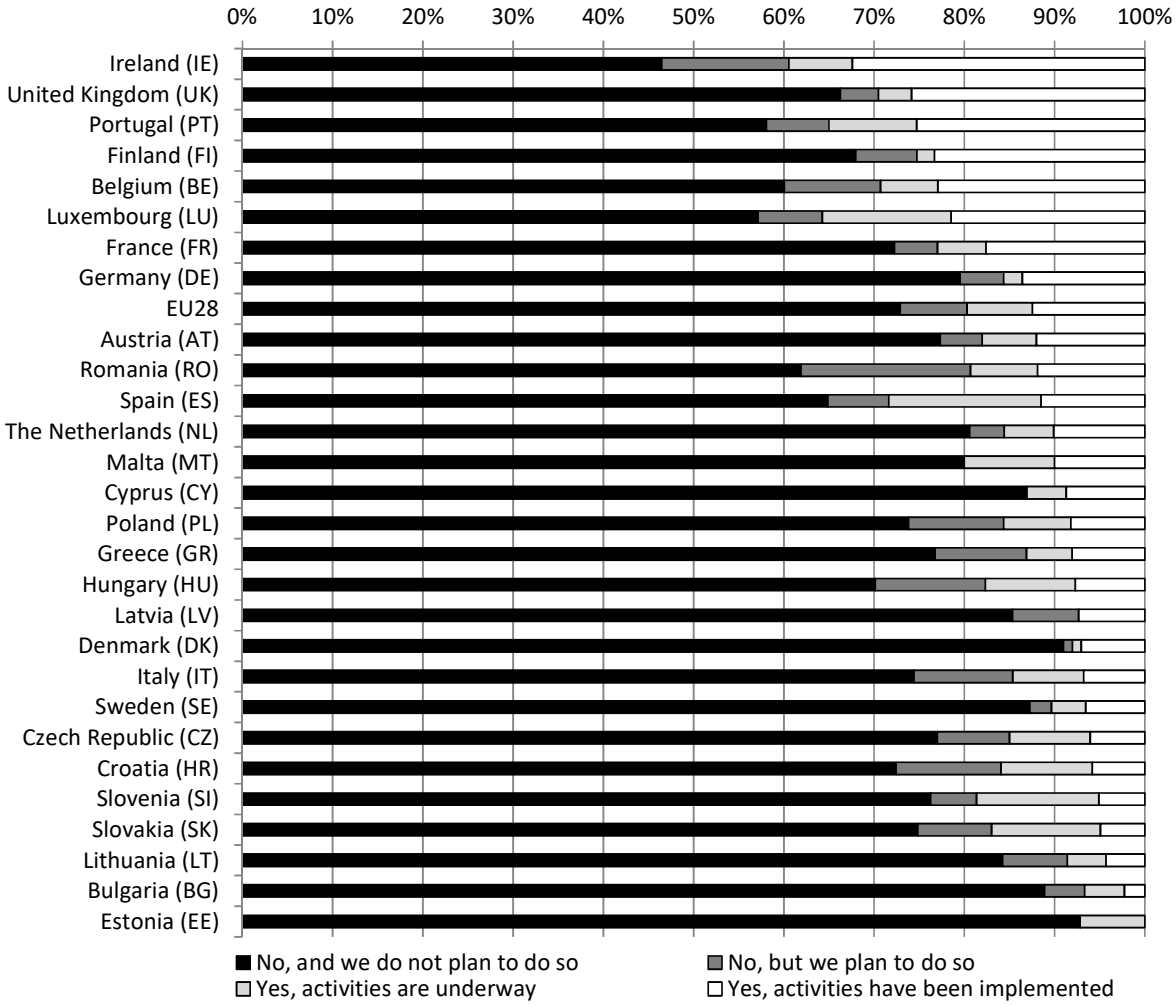
Figure 1. European countries by percentage of SMEs investing more than 20% of 2015 turnover in R&D and percentage of SMEs that undertook at least one CE activity in the last three years



555 **Figure 2. Re-planning the way water is used to minimize usage and maximize re-usage (in the last 3**
556 **years)**



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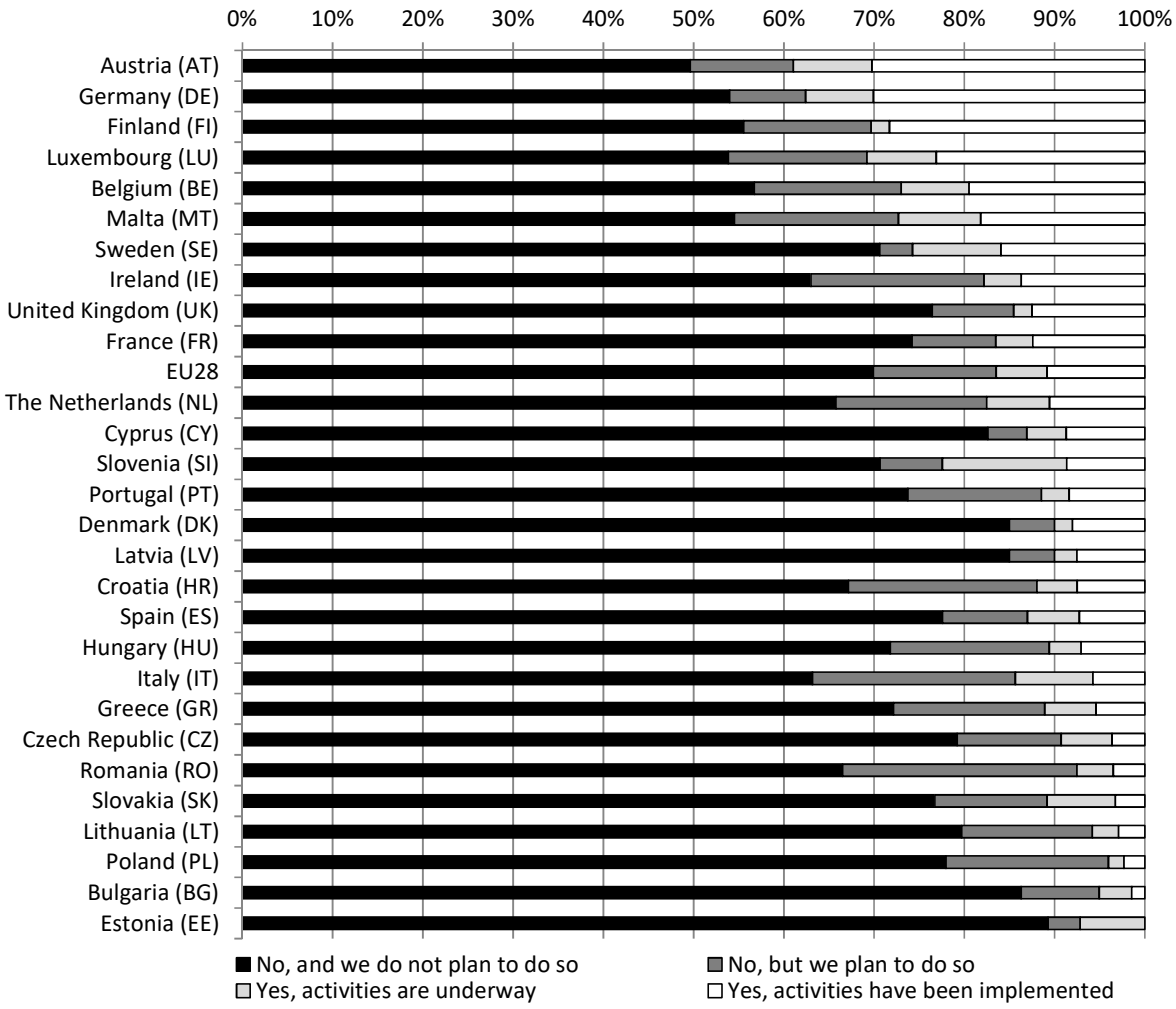
559 **Figure 3. Use of renewable energy (in the last 3 years).**



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562 **Figure 4. Re-planning energy usage to minimize consumption (in the last 3 years).**

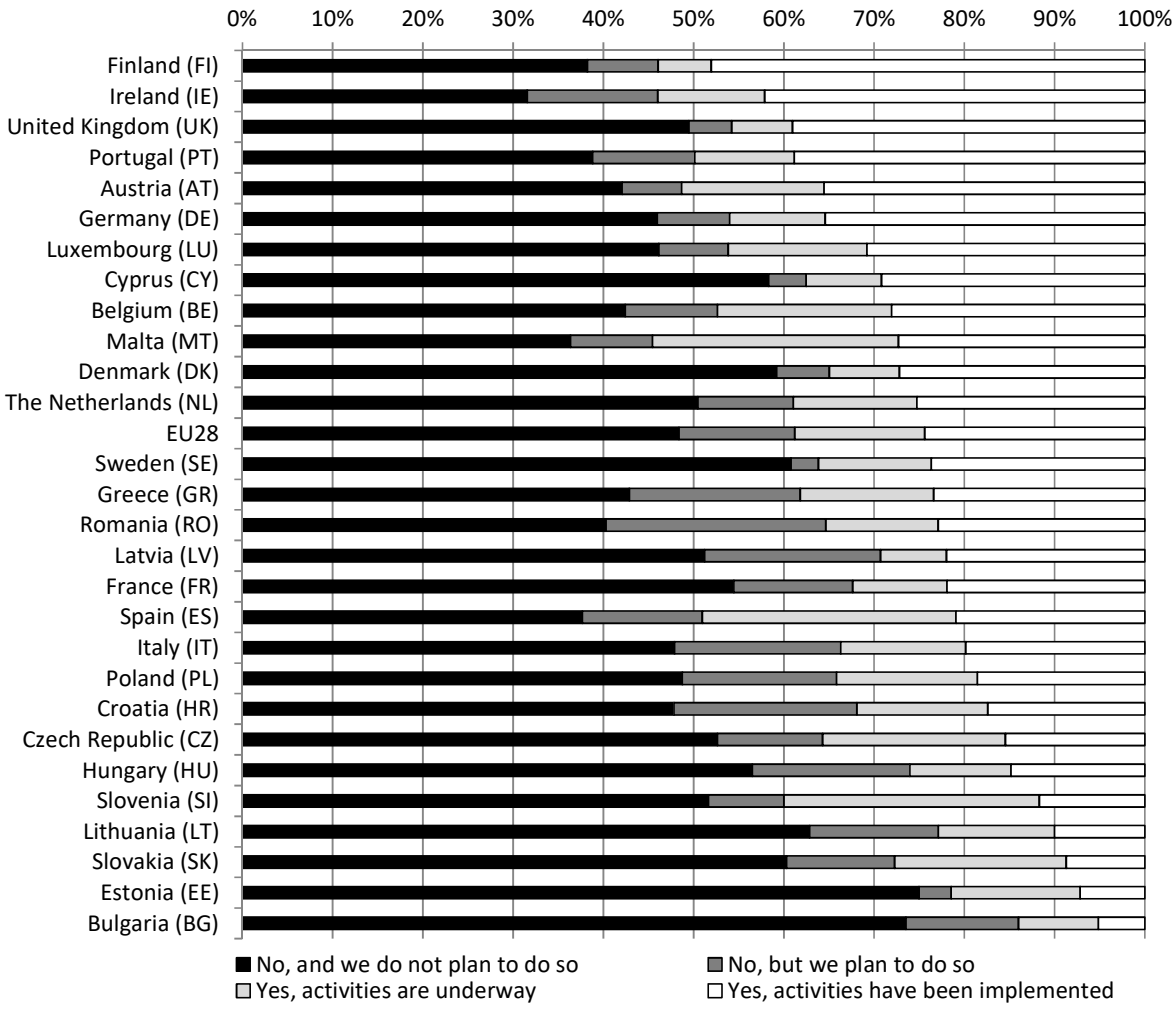

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Figure 5. Minimizing waste by recycling or reusing waste or selling it to another company (in the last 3 years).

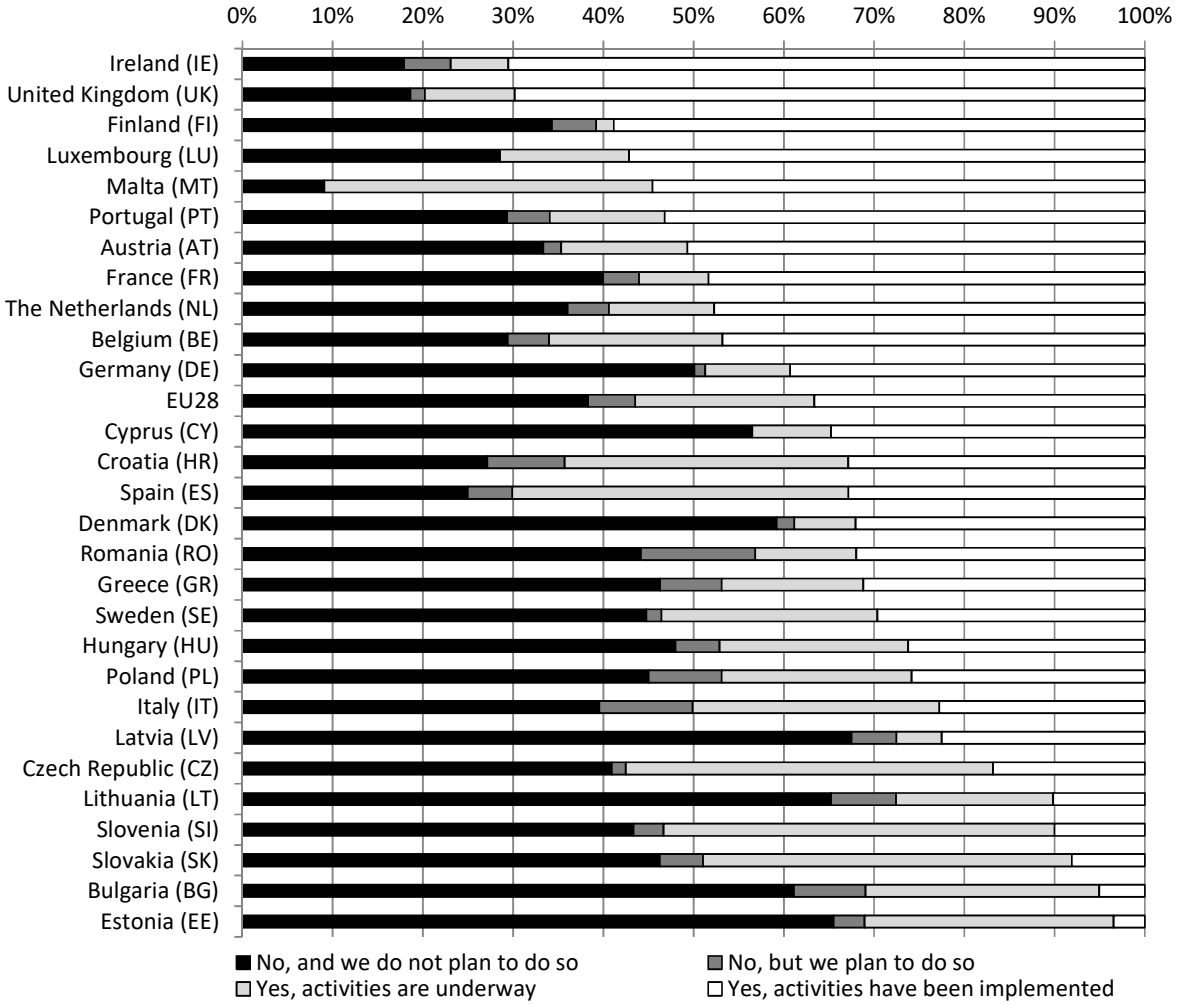
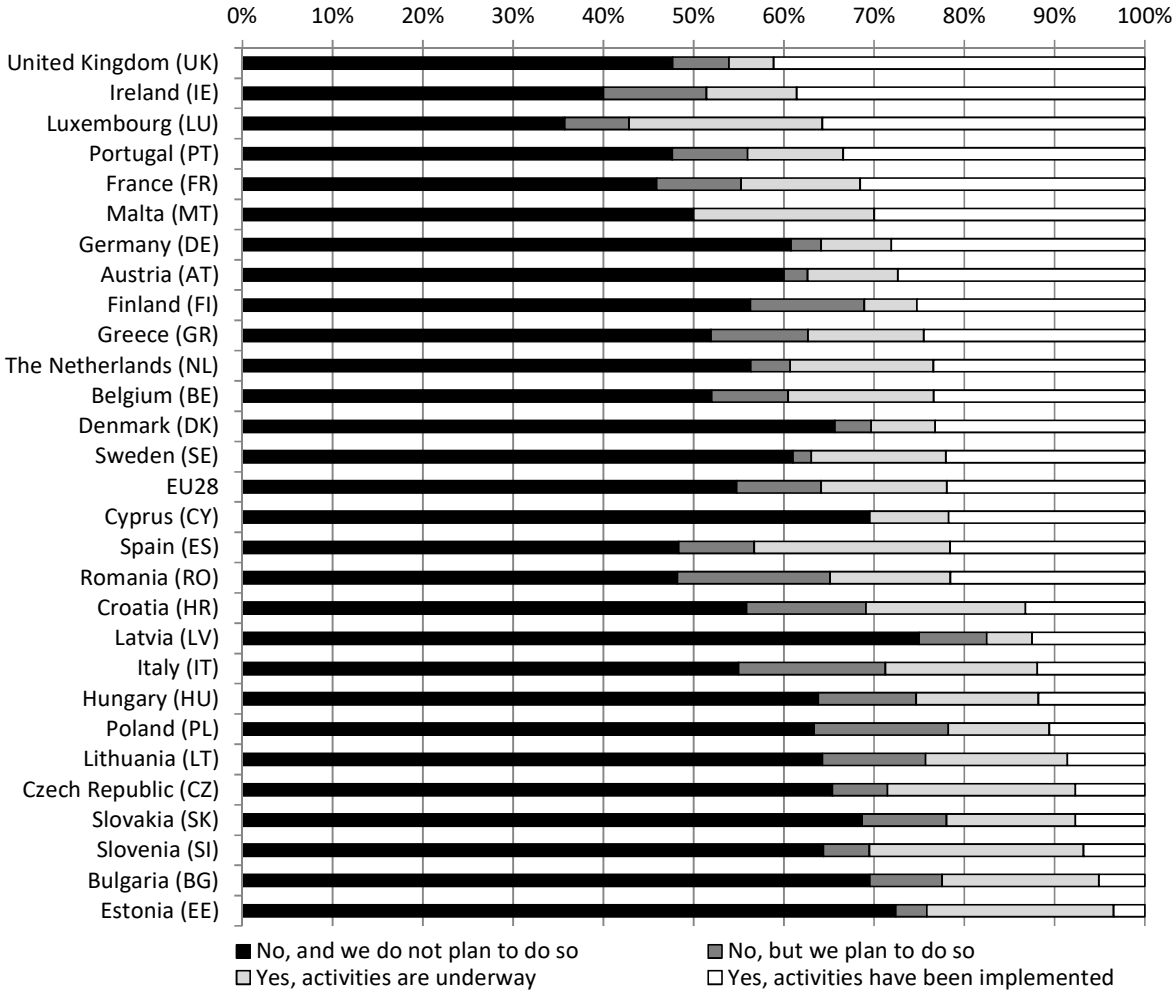


Figure 6. Redesigning products and services to minimize the use of materials or using recycled materials (in the last 3 years).



575 **Table 1. Overall characterization of the sample.**

	Undertook some circular economy related activity in past 3 years	Did not undertake circular economy related activities in past 3 years	Total
	73.18	26.82	
Number of employees (full-time equivalent) ***			
1 to 9 employees	91.67	95.36	92.66
10 to 49 employees	7.05	4.20	6.28
50 to 250 employees	1.29	0.43	1.06
Date firm established			
Before 1 January 2010	80.69	79.89	80.47
Between 1 January 2010 and 1 January 2015	16.95	17.40	17.07
After 1 January 2015	2.36	2.71	2.46
Firm's total turnover in 2015 ***			
Less than 25 000 euros	10.23	17.06	12.04
More than 25 000 to 50 000 euros	10.12	11.92	10.59
More than 50 000 to 100 000 euros	12.56	12.44	12.53
More than 100 000 to 250 000 euros	19.37	17.23	18.81
More than 250 000 to 500 000 euros	16.41	16.41	16.41
More than 500 000 to 2 million euros	19.14	16.60	18.47
More than 2 to 10 million euros	7.27	5.61	6.83
More than 10 million euros	4.90	2.73	4.33
Products/services being sold (multiple choice)			
Products directly to consumers ***	45.84	36.12	43.23
Products to companies or other organizations ***	39.17	30.37	36.81
Services directly to consumers ***	45.07	38.90	43.42
Services to companies or other organizations	51.08	50.33	50.88
Firm's turnover in 2015 invested in R & D (%) ***			
Less than 5%	78.05	86.11	75.26
From 5% to 9.9%	8.85	5.83	7.54
From 10% to 14.9%	6.01	2.97	4.87
From 15% to 19.9%	1.75	0.77	1.39
20% or more	5.33	4.32	4.75

576 Note: *** $p < 0.001$

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578 **Table 2. Country-level overview of firms: Company size and products.**

Country	Number of employees (full-time equivalent)			Products/services being sold (multiple choice: Yes)			
	1 to 9 employees	10 to 49 employees	50 to 250 employees	Products directly to consumers	Products to companies or other organizations	Services directly to consumers	Services to companies or other organizations
Austria (AT)	86.93	11.11	1.96	47.06	43.14	50.98	53.59
Belgium (BE)	94.38	4.87	0.75	52.81	42.54	49.06	55.06
Bulgaria (BG)	90.97	7.64	1.39	38.89	30.56	37.76	44.06
Croatia (HR)	91.43	7.14	1.43	35.71	45.71	39.13	55.07
Cyprus (CY)	95.65	4.35	0.00	54.17	54.17	34.78	39.13
Czech Republic (CZ)	96.10	3.25	0.65	40.91	38.23	51.40	52.60
Denmark (DK)	89.42	8.65	1.92	31.73	53.33	30.77	55.77
Estonia (EE)	92.86	7.14	0.00	25.00	27.59	50.00	72.41
Finland (FI)	92.23	6.80	0.97	37.50	43.69	56.73	75.00
France (FR)	94.95	4.40	0.65	54.55	43.58	55.41	53.03
Germany (DE)	81.52	15.81	2.67	39.33	40.91	41.30	54.25
Greece (GR)	97.05	2.65	0.29	37.17	48.53	35.10	49.26
Hungary (HU)	93.91	5.22	0.87	40.61	53.91	37.55	62.88
Ireland (IE)	89.87	6.33	3.80	48.10	22.78	49.37	41.77
Italy (IT)	94.71	4.77	0.52	44.62	23.33	34.33	33.22
Latvia (LV)	88.10	9.52	2.38	38.10	38.10	48.78	64.29
Lithuania (LT)	91.43	7.14	1.43	41.43	31.43	47.89	50.70
Luxembourg (LU)	85.71	14.29	0.00	50.00	50.00	50.00	64.29
Malta (MT)	91.67	8.33	0.00	45.45	50.00	41.67	45.45
Poland (PL)	95.13	3.89	0.97	42.92	42.78	48.68	65.69
Portugal (PT)	95.41	4.05	0.54	54.18	38.92	48.11	53.24
Romania (RO)	87.92	10.14	1.93	37.20	22.22	33.33	54.11
Slovakia (SK)	96.81	2.66	0.53	32.45	25.00	47.62	47.87
Slovenia (SI)	93.55	4.84	1.61	35.48	54.10	32.26	57.38
Spain (ES)	94.46	4.90	0.64	30.88	35.79	37.73	53.32
Sweden (SE)	94.06	4.95	0.99	31.68	40.92	36.42	74.83
The Netherlands (NL)	95.03	4.05	0.92	38.86	44.01	37.38	61.33
United Kingdom (UK)	88.44	9.79	1.77	53.72	28.45	51.83	38.61

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581 **Table 3. Country-level overview of SMEs: R & D and Circular economy.**

Country	Firm's turnover in 2015 invested in R & D (%)					Undertook some circular economy related activity (Yes)
	Less than 5%	From 5% to 9.9%	From 10% to 14.9%	From 15% to 19.9%	20% or more	
Malta (MT)	77.78	11.11	11.11	0.00	0.00	91.67
Ireland (IE)	74.32	13.51	6.76	0.00	5.41	88.61
Luxembourg (LU)	76.92	7.69	7.69	0.00	7.69	85.71
Spain (ES)	79.20	8.21	8.11	1.53	2.96	84.74
Austria (AT)	80.14	9.59	4.79	0.00	5.48	84.21
United Kingdom (UK)	81.74	6.04	3.51	1.26	7.44	84.06
Belgium (BE)	77.20	9.60	6.00	3.20	4.00	83.96
Portugal (PT)	86.23	6.29	3.89	0.30	3.29	82.21
Finland (FI)	81.00	8.00	6.00	0.00	5.00	78.64
Germany (DE)	78.65	6.29	6.63	1.24	7.19	77.87
France (FR)	88.95	5.56	3.34	0.52	1.63	74.10
Greece (GR)	79.26	9.29	3.41	2.48	5.57	73.45
Croatia (HR)	83.08	9.23	4.62	1.54	1.54	73.16
The Netherlands (NL)	74.25	11.84	7.89	1.50	4.51	73.11
Sweden (SE)	87.12	3.39	3.39	1.69	4.41	71.29
Czech Republic (CZ)	78.26	7.97	3.86	2.66	7.25	70.35
Slovenia (SI)	68.33	10.00	8.33	3.33	10.00	69.35
Cyprus (CY)	75.00	12.50	4.17	0.00	8.33	66.67
Italy (IT)	79.45	9.31	4.63	1.86	4.75	66.61
Denmark (DK)	80.61	6.12	4.08	2.04	7.14	62.50
Slovakia (SK)	88.70	4.52	2.26	0.56	3.95	62.23
Poland (PL)	67.97	14.06	6.67	2.03	9.28	62.03
Romania (RO)	63.68	7.96	8.46	4.48	15.42	61.84
Hungary (HU)	84.91	8.96	2.36	0.94	2.83	56.96
Latvia (LV)	82.93	7.32	4.88	0.00	4.88	53.66
Lithuania (LT)	89.86	2.90	4.35	0.00	2.90	47.14
Estonia (EE)	89.29	3.57	3.57	0.00	3.57	44.83
Bulgaria (BG)	91.43	1.43	4.29	0.00	2.86	43.75

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592 **Table 4. Multilevel binary probit regression results.**

	Undertook some circular economy related activity in past 3 years		
	Estimate	**S.E.**	**p-value**
Level 1 - Regression model: Fixed effects			
Number of employees (full-time equivalent)			
1 to 9 employees (ref.)			
10 to 49 employees	0.174	0.078	0.026
50 to 250 employees	0.401	0.103	<0.001
Date firm established			
Before 1 January 2010 (ref.)			
Between 1 January 2010 and 1 January 2015	0.071	0.054	0.190
After 1 January 2015	-0.004	0.183	0.983
Firm's total turnover in 2015			
Less than 25,000 euros (ref.)			
More than 25,000 to 50,000 €	0.104	0.109	0.339
More than 50,000 to 100,000 €	0.057	0.111	0.605
More than 100,000 to 250,000 €	0.175	0.083	0.036
More than 250,000 to 500,000 €	0.241	0.090	0.008
More than 500,000 to 2 million €	0.388	0.105	<0.001
More than 2 to 10 million €	0.369	0.148	0.013
More than 10 million €	0.662	0.165	<0.001
Products/services being sold (multiple choice)			
Products directly to consumers	0.182	0.058	0.002
Products to companies or other organizations	0.258	0.072	<0.001
Services directly to consumers	0.285	0.049	<0.001
Services to companies or other organizations	0.044	0.073	0.547
Firm's turnover in 2015 invested in R & D (%)			
Less than 5% (ref.)			
From 5% to 9.9%	0.326	0.109	0.003
From 10% to 14.9%	0.460	0.097	<0.001
From 15% to 19.9%	0.532	0.226	0.019
20% or more	0.378	0.147	0.010
Thresholds			
τ_1	0.015	0.124	0.906
Level 2 - Random effects			
Var(u_j)	0.129	0.034	<0.001
ICC	0.114		

Note: Residual variance equals 1.

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Table 5. Multilevel ordinal probit regression results.

	Re-planning the way water is used to minimize usage and maximize re-usage (in the last 3 years)?			Use of renewable energy (in the last 3 years)?			Re-planning energy usage to minimize consumption (in the last 3 years)?			Minimizing waste by recycling or reusing waste or selling it to another company (in the last 3 years)?			Redesigning products and services to minimize the use of materials or using recycled materials (in the last 3 years)?		
	Estimate	**S.E.**	**p-value**	**Estimate**	**S.E.**	**p-value**	**Estimate**	**S.E.**	**p-value**	**Estimate**	**S.E.**	**p-value**	**Estimate**	**S.E.**	**p-value**
Level 1 - Regression model: Fixed effects															
Number of employees (full-time equivalent)															
10 to 49 employees	0.131	0.053	0.013	0.111	0.048	0.020	0.137	0.042	0.001	0.273	0.049	<0.001	0.104	0.046	0.022
50 to 250 employees	0244	0.080	0.002	0.271	0.082	0.001	0.301	0.052	<0.001	0.431	0.052	<0.001	0.230	0.071	0.001
Date firm established															
Between 1 January 2010 and 1 January 2015	-0.052	0.032	0.103	-0.044	0.041	0.288	-0.050	0.034	0.145	0.005	0.044	0.912	0.080	0.041	0.051
After 1 January 2015	0.018	0.120	0.883	-0.299	0.143	0.037	-0.027	0.133	0.839	0.013	0.117	0.909	-0.011	0.111	0.921
Firm's total turnover in 2015															
More than 25,000 to 50,000 €	-0.037	0.081	0.649	-0.223	0.067	0.001	0.007	0.062	0.909	0.130	0.054	0.015	-0.017	0.066	0.799
More than 50,000 to 100,000 €	-0.073	0.070	0.296	-0.069	0.072	0.339	-0.055	0.065	0.400	0.129	0.056	0.022	0.019	0.059	0.746
More than 100,000 to 250,000 €	-0.155	0.091	0.090	-0.044	0.071	0.529	0.045	0.072	0.535	0.189	0.054	<0.001	0.062	0.068	0.365
More than 250,000 to 500,000 €	-0.079	0.089	0.376	0.012	0.068	0.861	0.104	0.067	0.124	0.303	0.058	<0.001	0.094	0.055	0.085
More than 500,000 to 2 million €	-0.076	0.080	0.340	-0.005	0.070	0.946	0.157	0.065	0.016	0.271	0.055	<0.001	0.152	0.066	0.021
More than 2 to 10 million €	-0.104	0.099	0.292	0.068	0.094	0.469	0.181	0.077	0.018	0.341	0.076	<0.001	0.244	0.068	<0.001
More than 10 million €	0.260	0.110	0.019	0.240	0.122	0.048	0.398	0.082	<0.001	0.388	0.068	<0.001	0.189	0.095	0.046
Products/services being sold (multiple choice)															
Products directly to consumers	0.112	0.033	0.001	0.075	0.045	0.095	0.180	0.036	<0.001	0.159	0.032	<0.001	0.028	0.037	0.447
Products to companies or other organizations	0.052	0.041	0.206	0.082	0.053	0.121	0.039	0.044	0.378	0.160	0.034	<0.001	0.134	0.039	0.001
Services directly to consumers	0.273	0.039	<0.001	0.225	0.036	<0.001	0.208	0.028	<0.001	0.206	0.030	<0.001	0.236	0.024	<0.001
Services to companies or other organizations	-0.049	0.041	0.238	0.031	0.042	0.473	-0.033	0.024	0.160	0.003	0.037	0.925	0.018	0.044	0.688
Firm's turnover in 2015 invested in R & D															
From 5% to 9.9%	0.202	0.038	<0.001	0.290	0.047	<0.001	0.272	0.056	<0.001	0.147	0.048	0.002	0.413	0.052	<0.001
From 10% to 14.9%	0.243	0.059	<0.001	0.351	0.076	<0.001	0.274	0.043	<0.001	0.236	0.059	<0.001	0.439	0.057	<0.001
From 15% to 19.9%	0.404	0.167	0.015	0.348	0.097	<0.001	0.326	0.115	0.004	0.196	0.107	0.068	0.505	0.121	<0.001
20% or more	0.324	0.070	<0.001	0.364	0.060	<0.001	0.270	0.086	0.002	0.159	0.081	0.049	0.344	0.073	<0.001
Thresholds															
τ_1	0.860	0.103	<0.001	0.790	0.092	<0.001	0.294	0.083	<0.001	0.225	0.091	0.014	0.563	0.089	<0.001
τ_2	1.125	0.099	<0.001	1.275	0.096	<0.001	0.626	0.089	<0.001	0.359	0.091	<0.001	0.806	0.092	<0.001
τ_3	1.437	0.099	<0.001	1.546	0.106	<0.001	1.055	0.095	<0.001	0.903	0.116	<0.001	1.256	0.110	<0.001
Level 2 - Random effects															
Var(u_j)	0.116	0.029	<0.001	0.093	0.020	<0.001	0.069	0.021	0.001	0.178	0.047	<0.001	0.065	0.013	<0.001
ICC	0.104			0.085			0.065			0.151			0.061		

Note: Residual variance equals 1. Reference categories are the same as in Table 4.