

1 **The use of circular economy practices in SMEs across the EU**

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12
13 **Abstract**

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

27
28 Keywords: Circular economy, small and medium-sized enterprises (SMEs), cross-cultural research,
29 multilevel modeling, European Union.

31 **1 Introduction**

32 The concept of the circular economy (CE) was introduced at the end of the last century; since the
33 first scientific papers on the topic were published in the 1980s, it has received increasing attention
34 from scholars (Lieder and Rashid, 2016). Although this vast literature offers many definitions of the
35 circular economy, the key concept refers to harmonizing economic growth and environmental
36 protection. A popular definition of the circular economy takes advantage of the easy-to-remember
37 3Rs: reduction, reusing, and recycling, and it describes the practical approach to the concept (see,
38 for example, Liu et al., 2017). The Ellen MacArthur Foundation (2015) proposes a more
39 comprehensive definition that includes environmental and economic advantages, according to which
40 the circular economy is “an industrial economy that is restorative or regenerative by intention and
41 design”. This recent definition incorporates the idea of ensuring the safe entry of bio-nutrients in the
42 biological sphere. Another important notion in this context is the difference between the circular
43 economy and the linear production system: whereas the linear system perceives end-of-life products
44 as waste, the circular economy sees them as resources, and this also has an impact on the
45 environment, on resource scarcity, and on economic benefits. Other papers (e.g., Kopnina, 2018)
46 underline the difference between CE and other paradigms of sustainability, like the quite popular
47 cradle-to-cradle (C2C) developed by McDonough and Braungart (2002). As its name suggests, the
48 aim of C2C is to return raw materials that have been taken from nature back to nature. C2C goes
49 beyond the 3Rs principle by recognizing that although the 3Rs are a way of limiting environmental
50 damage, they do not eliminate waste.

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

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

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

83 Small and medium-sized enterprises (SMEs) represent 99% of all businesses in the EU¹ varying from
84 99.5% (Germany and Luxembourg) to 99.9% (France)². Between 2002 and 2010, the SMEs in EU had
85 a much higher employment growth rate (1% annually) than the large enterprises (0.5%)³; and in
86 recent years, they have created most of the new jobs. Not only are they a very big group, but they
87 also contribute to a large share of the overall pollution (ECEI, 2010). Nevertheless, specific research
88 on CE practices in the SME segment is scarce. This paper focuses on the use of circular economy
89 practices in the European Union (EU) by SMEs; specifically, it analyzes the activities of European
90 SMEs with regard to the circular economy. The European Union funds many projects fostering CE
91 practices in SMEs (<https://www.clustercollaboration.eu/>). Some recent literature focuses in
92 particular on the topic of barriers and enablers of implementing the circular economy by small and
93 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).

94 Schaltegger and Wagner (2011) studies the conditions under which sustainability innovation
95 emerges spontaneously in companies. They identify, for example, industry life cycle as a crucial
96 factor. del Rio Gonzàles (2005) identifies factors external and internal to the firm that stimulate the
97 adoption and diffusion of clean technology; while external factors relate mainly to regulations,
98 internal factors involve employees, organizational culture, brand image and reputation, competitive
99 advantage and strategic intent, and environmental management capacities. It is important to
100 understand that SMEs are not smaller versions of their larger counterparts (Welsh and White, 1981).
101 Most of these internal conditions are influenced by a more difficult separation between decision
102 making and management and the ownership of the capital. Firm size is particularly relevant as
103 medium-sized organizations, both in terms of the number of employees and turnover, are more
104 engaged in CE practices (Hoogendoorn et al., 2015). Another important factor is the type of market
105 being served. Hoogendoorn et al. (2015) show that SMEs selling directly to consumers are just as
106 likely to engage in greening processes as those selling to other companies. Finally, the firm's age has
107 also been researched as an influencer of the firm's engagement in CE practices. Neubaum et al.
108 (2004) conclude that scarcity of resources and concern about survival may have a negative influence,
109 whereas Hockerts and Wüstenhagen (2010) show the opposite relation. On the other hand,
110 Hoogendoorn et al. (2015) found that age did not have any influence on environmental practices.

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

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

130

131 **2 Methods**

132 **2.1 Eurobarometer data set**

133 This research uses data from the Flash Eurobarometer 441 (European SMEs and the circular
134 economy) conducted in the 28 EU Member States⁴ in April 2016 and involves 10,618 interviews
135 under the supervision of the European Commission (European Commission, 2016).⁵ This is a unique
136 and representative sample of EU firms selected by multi-stage random sampling that allows a
137 comparative study of different countries as data is collected using a common methodology. Firms
138 employing from 1 to 250 persons within manufacturing, retail, and services are the respondent
139 units. Questions are about circular economy-related activities in the last three years and
140 characteristics of the firms. The questionnaire is translated into the native language of the
141 interviewee and back-translated to ensure the quality of the questionnaire. The European weights,
142 reproducing the actual “number of cases for each country”, ponder the sample size with the
143 universe size (derived from EUROSTAT population data or from other national statistics institutions)
144 to obtain a stratified sample, and were applied to the data set. This methodological care enhances
145 the usefulness of this secondary data for scientific research, even though contents are constrained
146 and selected based on policy-oriented priorities of the European Commission.

147

148 **2.2 The multilevel model**

149 The data at our disposal are hierarchical, i.e., SMEs are nested into countries; this structure requires
150 appropriate models to be used for the analysis, something that has not been previously done in the
151 literature (e.g., Hoogendoorn et al., 2015). The study applies a multilevel ordinal probit regression
152 model to be estimated simultaneously at two levels: the individual level measures the impact that
153 the characteristics of the firms in each country have on their CE intentions and behaviors; the
154 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

155 same country share a set of characteristics, the traditional assumption of independence is violated.
 156 Such a nested structure is taken into account by the multilevel modeling, making it a particularly
 157 suitable model to apply in our analysis (Hedeker and Gibbons, 1994; Hox, 2002; Snijders and Bosker,
 158 2012). For example, estimating an ordinary linear regression model on hierarchical data is not
 159 correct since (i) residuals may not be assumed independent and (ii) it is not possible to disentangle
 160 variability at the various levels (Snijders and Bosker, 2012). The value y_{ijk} measures the response of
 161 individual i (SME i) from country j on the item k regarding CE intentions on an ordinal scale. Ordinal
 162 data is modeled by assuming an underlying continuous latent variable, y_{ijk}^* , that measures the
 163 propensity of individual i in country j to choose category m and is related with the ordinal item by
 164 thresholds:

$$165 \quad y_{ijk} = m, \text{ if } \tau_{k,m-1} < y_{ijk}^* < \tau_{k,m} \quad (1)$$

166 where $\tau_{k,m}$ is the threshold for item k that defines the categories $m = 0, \dots, M$, with $\tau_{k,0} = -\infty$ and
 167 $\tau_{k,M} = \infty$. Thus, higher values of y_{ijk}^* indicate higher categories of the observed ordinal variable. For
 168 an M -level ordinal variable, $M - 1$ thresholds are required. The ordinal variables are explained by a
 169 set of P observed covariates (x_{ijp}). The linear component of the model is given by $y_{ijk}^* = \boldsymbol{\beta} \mathbf{x}'_{ij} +$
 170 $u_j + \epsilon_{ij}$, where \mathbf{x}_{ij} is the vector that contains the observed covariates for observation i in
 171 cluster/country j , $\boldsymbol{\beta}$ is the vector of regression parameters (fixed effects), u_j is the random effect for
 172 cluster/country j , and ϵ_{ij} is the error term. The thresholds replace the intercept in the model,
 173 whereas the random effect (u_j) represents factors affecting y_{ijk}^* that are shared by all units within
 174 cluster/country j , after controlling individual covariates. The multilevel ordinal probit regression
 175 model assumes standard normal errors and that random intercepts (u_j) are independent of the
 176 errors (ϵ_{ij}) and normally distributed: $u_j \sim N(0, \sigma_u^2)$. The intra-class correlation coefficient (ICC) is the
 177 proportion of the total dispersion that is explained by the country level: $ICC = \sigma_u^2 / (1 + \sigma_u^2)$.
 178 Descriptive statistics and chi-square tests are used to describe the data and test independence
 179 between non-metric variables, respectively. In hypothesis testing, the maximum probability of type I
 180 error (level of significance) is set at 0.05.

181

182 **2.3 Variables**

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

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

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

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

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

215 **3. Results**

216 **3.1 Sample characterization**

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

235 [Table 1 about here.]

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

244 [Table 2 about here.]

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

248 Table 3 reports figures on the adoption of circular economy practices at the country level. Countries
249 are ranked in descending order for the percentage of the sampled firms' adoption of at least one
250 circular economy practice in the last three years. The most virtuous country is Malta, where over
251 90% of SMEs have undertaken at least one of these five CE following activities. The lowest
252 percentage (43.8%) is observed in Bulgaria; there is a non-negligible heterogeneity in the
253 percentages referring to all 28 EU countries. Less heterogeneity appears in the percentage of total
254 turnover devoted by firms to research and development in 2015.

255 [Table 3 about here.]

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

272 [Figure 1 about here.]

273

274

275

276 **3.2 Overall circular economy-related activity**

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

288 [Table 4 about here.]

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

294

295 **3.3 Re-planning the way water is used to minimize usage and maximize re-usage**

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

304 [Figure 2 about here.]

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

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

313 [Table 5 about here.]

314

315 **3.4 Use of renewable energy**

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

325 [Figure 3 about here.]

326 The results of the estimation of the ordinal regression model (Table 5) are very similar to those
327 described in the previous paragraph, except for the negative effect of firms founded in the last year;
328 in this case, younger firms are less prone to adoption, and the effect is also non-significant for firms
329 that sell products directly to consumers. The country level accounts for 8.5% (ICC). With regards to
330 total turnover, it has a negative effect on the adoption of this policy when it is very low, below
331 50,000 Euros, but a positive effect when very high, over 10 million.

332

333 **3.5 Re-planning energy usage to minimize consumption**

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

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

346 [Figure 4 about here.]

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

352

353 **3.6 Minimizing waste by recycling or reusing waste or selling it to another company**

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

361 [Figure 5 about here.]

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

367

368 **3.7 Redesigning products and services to minimize the use of materials or using recycled materials**

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

373 [Figure 6 about here.]

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

378

379 **4 Discussion and conclusion**

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

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

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

398 Minimizing waste by recycling or reusing waste or selling it to another company is the CE practice
399 adopted most by SMEs (55.4% of firms have adopted or are about to adopt this policy), followed by
400 re-planning energy usage to minimize consumption (37.7% of SMEs) and redesigning products and
401 services to minimize the use of materials or using recycled material (34.4%). This last practice goes
402 beyond efficiency as it involves a fundamental reassessment of the use of resources; thus, the fact
403 that a very high percentage of firms do not intend to implement it in almost all 28 EU countries is a
404 striking result. The use of renewable energy was adopted or considered for the immediate future by
405 only 15% of firms, making it the CE practice with the lowest percentage. However, re-planning the
406 way water is used to minimize usage and maximize re-usage had only a slightly higher percentage
407 (18.8%).

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

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

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

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

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

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

457 Green competences in European SMEs are an additional topic of interest, namely, finding out how
458 many workers perform green jobs and the importance of these skills in the eyes of managers. The
459 relationship between CE practices, employment, and green skills has recently found space in the
460 reference literature (see, for example, Ghisellini et al. 2016) and seems a promising field to be
461 explored to explain the adoption of CE practices at firm and country levels. This is the case of SMEs
462 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).

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

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

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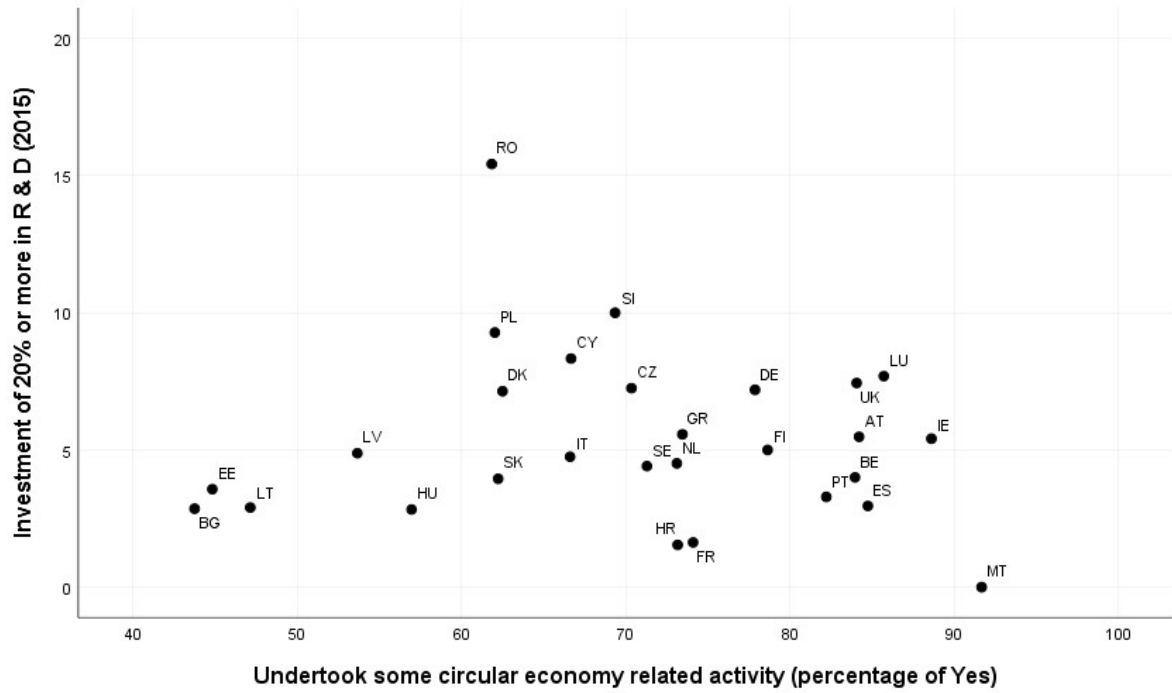
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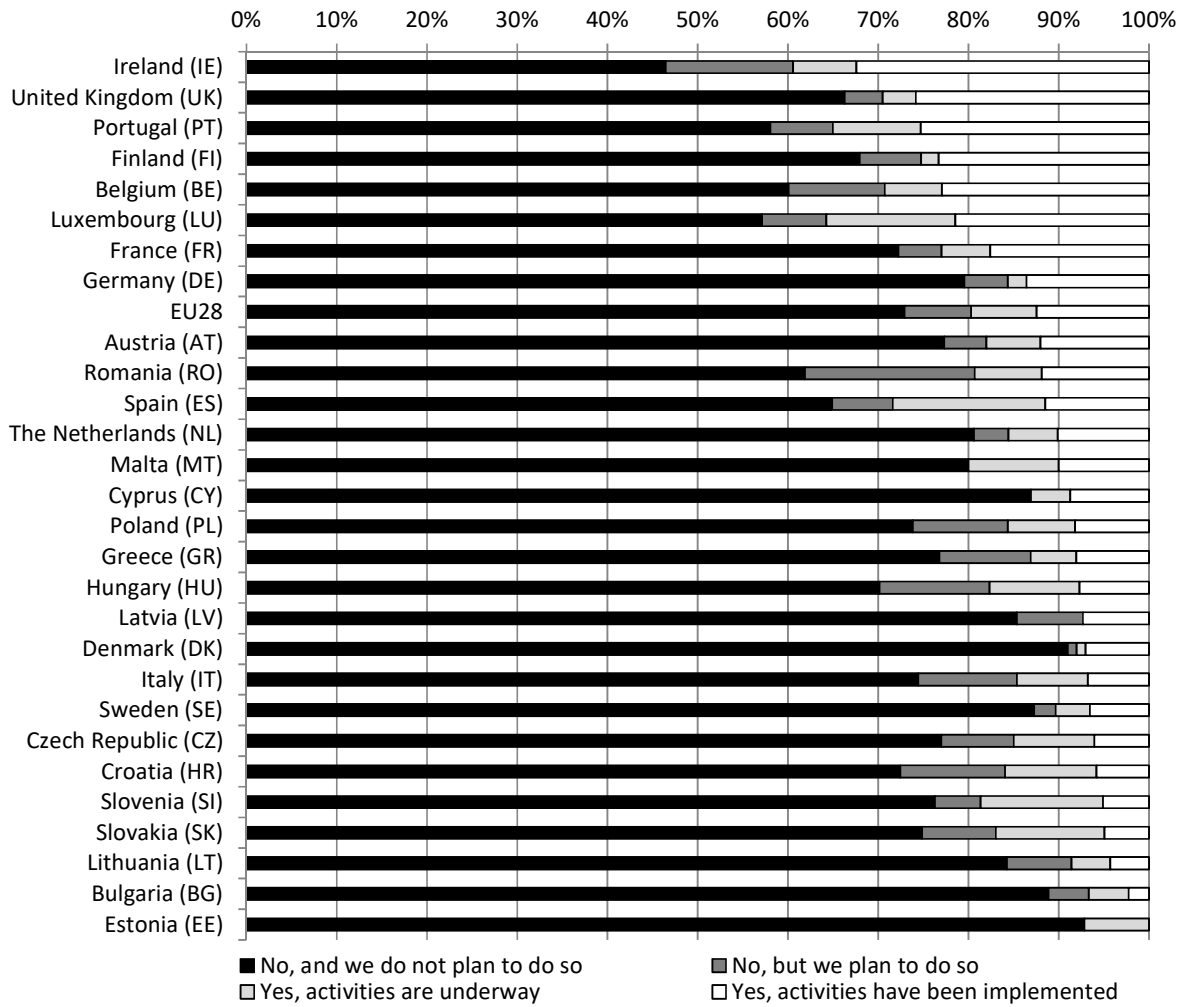
560 **Figure 1. European countries by percentage of SMEs investing more than 20% of 2015 turnover in**
 561 **R&D and percentage of SMEs that undertook at least one CE activity in the last three years**
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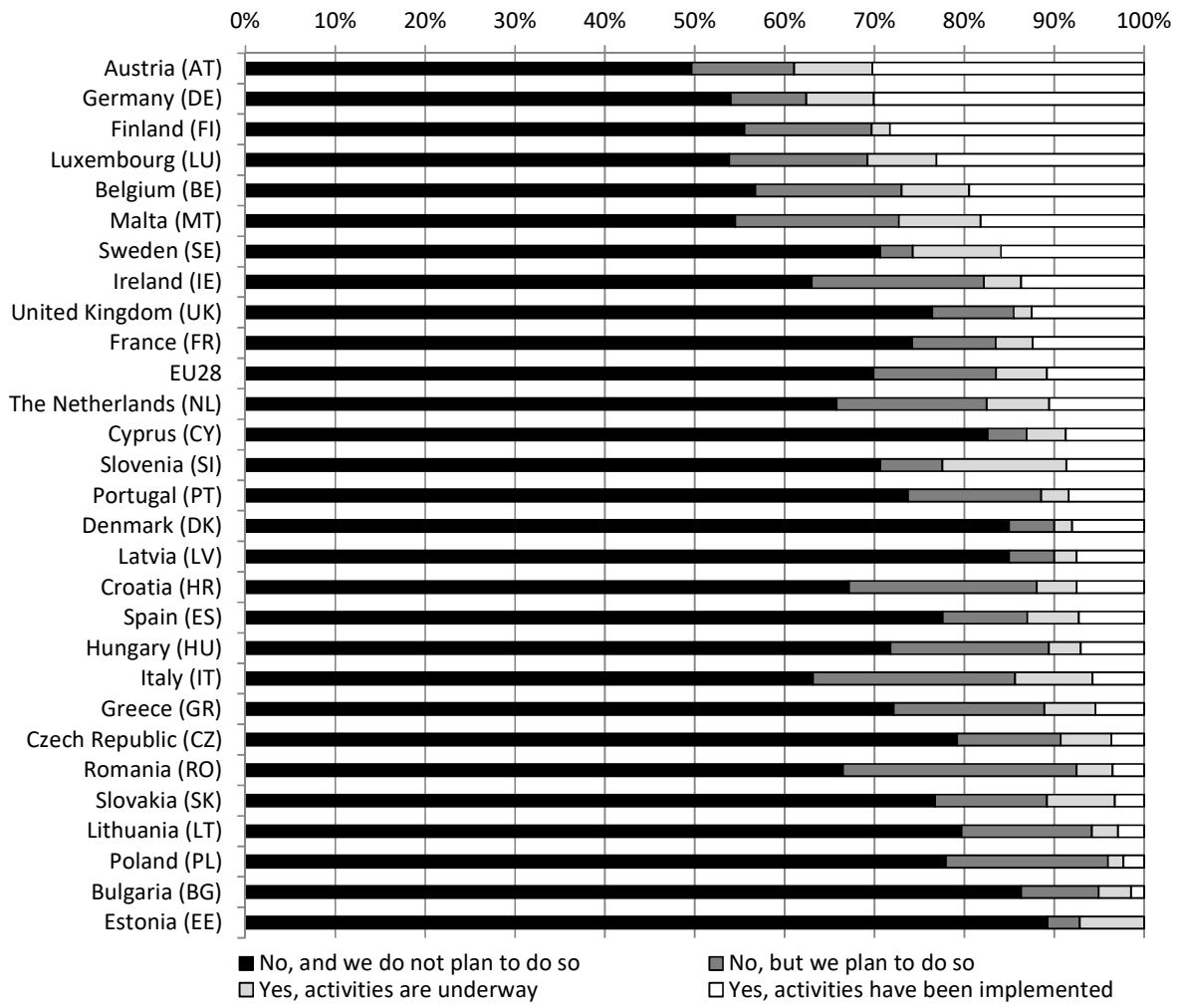
565 **Figure 2. Re-planning the way water is used to minimize usage and maximize re-usage (in the last 3**
 566 **years)**



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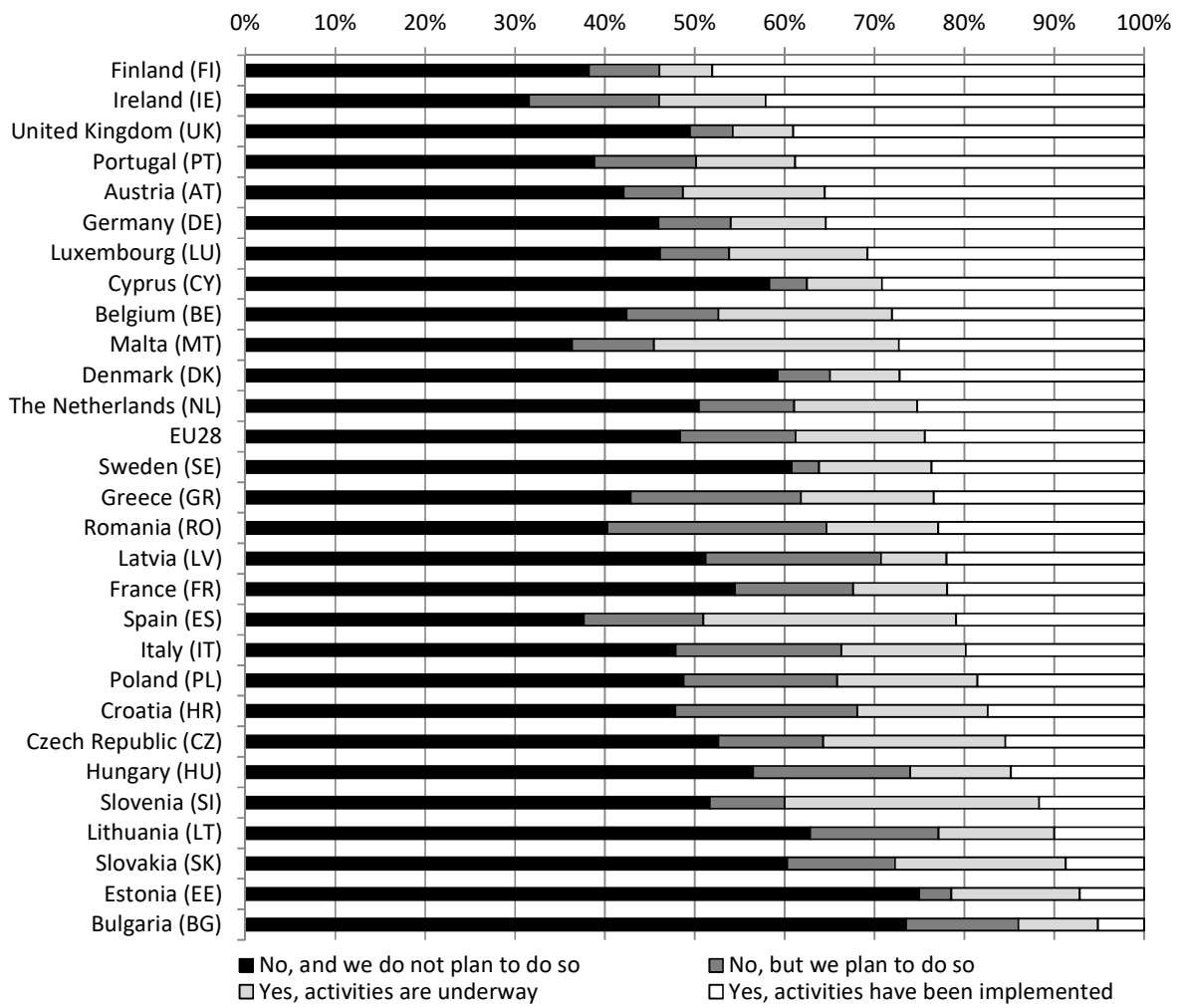
569 **Figure 3. Use of renewable energy (in the last 3 years).**



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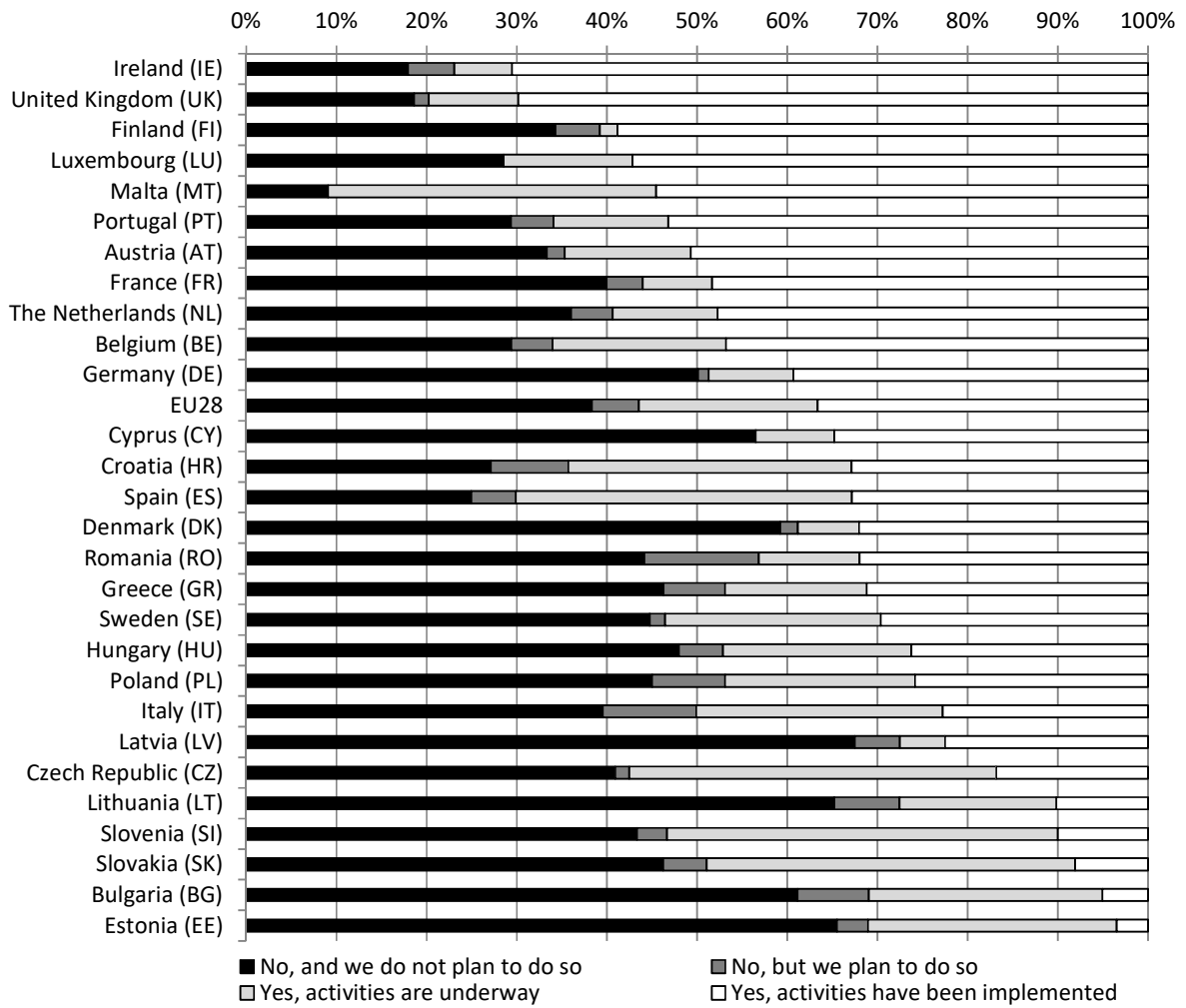
572 **Figure 4. Re-planning energy usage to minimize consumption (in the last 3 years).**



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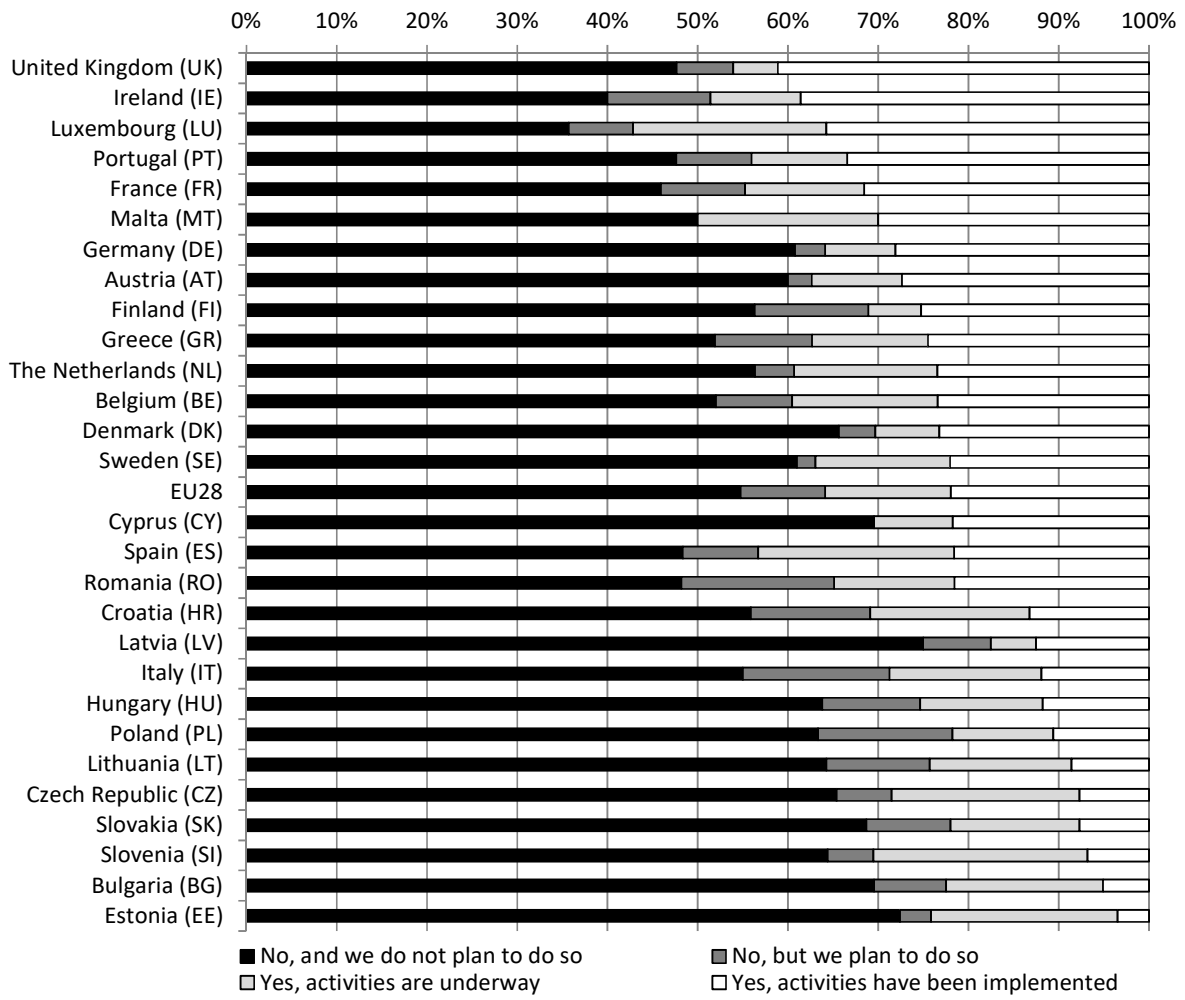
575 **Figure 5. Minimizing waste by recycling or reusing waste or selling it to another company (in the**
 576 **last 3 years).**



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



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585 **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

Note: *** p < 0.001

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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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591 **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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602 **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	0.244	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.