Sustainable development of small and medium-sized enterprises in the European Union: a taxonomy of circular economy practices

Abstract

This paper focuses on the implementation of circular economy (CE) practices in small and medium-sized firms in all 28 European Union (EU) countries. The analyses take into account the hierarchical nature of the collected data as firms are nested within EU countries, i.e., the heterogeneity between different types of firms and countries according to practices and attitudes towards CE. The multilevel latent class model identifies groups of firms and groups of EU countries that are homogeneous in terms of CE, i.e., how the homogeneous groups of SMEs are distributed across the groups of EU countries. These results, together with the fact that firms with similar CE attitudes and practices have different demographic and business profiles across groups of countries, shed further light on the topic of green behavior in the EU with implications for businesses' environmental policies. Moreover, indications emerge that European policies favoring the implementation of CE practices should be targeted at least for subgroups of European countries, considering the different composition by typology of SMEs operating in their territories and that, at the same time policies should be defined within each group of countries to account for the specific features of each of the four classes of SMEs.

Keywords

circular economy, sustainable development, small and medium-sized firms, European Union, environmental policy, latent class analysis

1 Introduction

Circular economy (CE) is now one of the top priorities in politics, policy, and economics. Although the concept appeared in the scientific literature at the end of the last century, it has been receiving increasing attention from stakeholders (firms, governments, and policymakers), practitioners, and scholars (Lieder and Rashid, 2016). The many definitions of CE found in the literature all refer to concern about environment

protection and exploitation of resources. Academics and practitioners increasingly see CE as a promising concept for sustainable development. Nevertheless, criticisms have been made of the superficiality and lack of systematic research on the concept and the resulting vague and separate ideas from different fields (Korhonen et al., 2018).

Liu et al. (2009) draw attention to the theory and practice of CE. The theory encompasses the principles of the ecological economy which recognize that the Earth's ecological system has limited resources and environmental capabilities. In practice, CE refers to all activities aimed at safeguarding the environment, preventing pollution, and fostering energy efficiency. A popular and simple definition of CE refers to the 3Rs – reducing, reusing, and recycling – to describe the practical approach to the concept (see, for example, Liu et al., 2017). A recent paper by Geissdoerfer et al. (2017) defines CE as "a regenerative system in which resources input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling", which encompasses almost all the aspects indicated above. Indeed, Kirchherr et al. (2017) analyzed 114 definitions of CE and concluded that although they combine reducing, reusing, and recycling activities, these may mean different things to different people.

Lieder and Rashid (2016) provide an extensive review of the research into the different relevant ideas and the most common practical implementations of CE. A number of complementary definitions of the concept emphasizing its different but important facets emerge from their work. Geng and Doberstein (2008), for example, define CE as the "realization of closed-loop material flow in the whole economic system", thus underlining eco-industrial development. In one of the first definitions of CE, Stahel (1982) also takes economic properties into account: "an economy based on a spiral-loop system that minimizes matter, energy-flow and environmental deterioration without restricting economic growth or social and technical progress". The Ellen MacArthur Foundation[1], a worldwide network of businesses, innovators, governments, cities, and universities founded in 2010 with the specific goal to accelerate the transition to CE, proposes a more comprehensive definition that includes environmental and economic advantages, according to which CE is "an industrial economy that is restorative or regenerative by intention and design" (Ellen MacArthur

[1] https://www.ellenmacarthurfoundation.org

Foundation, 2015). This recent definition incorporates the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. As the term CE implies, this approach requires a new way of thinking; more than simply saving or increasing efficiency, it refers to the flows in the living systems where the waste of one agent becomes food for another one. In biological cycles, food and biologically based materials are designed to feed back into the system through processes like composting and anaerobic digestion. Technical cycles recover and restore products, components, and materials through strategies like reusing, repairing, remanufacturing or recycling. CE favors the implementation of technical cycles. Various schools of thought were developed along these lines. One of the most important of these, the cradle to cradle philosophy, introduced by McDonough and Braungart (2002), states that waste from a production process must be a resource for new products. Performance economy (Stahel, 1982) emphasizes the CE's potential effect on the economic system through job creation, competitiveness, and savings; it also stresses the importance of selling services rather than goods. Industrial ecology aims to create closed-loop processes in which waste serves as an input, thus eliminating the notion of an undesirable by-product (Ehrenfeld, 2004). Finally, the recent concept of the blue economy favors eco-innovation in that a better understanding of our ocean or 'blue' resources allows us to go beyond the green economy to reach very sustainable worldwide development (Pauli, 2010).

Both consumption and the traditional production system are linear, not circular. Whereas the linear system perceives end-of-life products as waste, the CE sees them as inputs and this also has an impact on the environment, resource scarcity and bringing economic benefits. When implementing CE, policymakers play a very important role at the national and local levels.

This paper focuses on the implementation of CE practices by SMEs in the EU, exploring data collected by Flash Eurobarometer 441 survey. The specific contribution of our paper is to build multilevel models with these data in order to make a within and between country evaluation of heterogeneity in the adoption patterns of CE practices. Although the estimation of nonhierarchical models on nested data implies that observations are independent, this assumption is often violated in longitudinal studies, two-stage sampling designs, and multi-group analysis as there are cross country comparisons where data is collected in a large number of nations (see, for example, Wong and Mason, 1985).

Our research has the advantage of drawing on data about industries operating in all economic sectors in all EU countries. As our analyses take into account the hierarchical nature of this data, i.e., the fact that firms are nested within EU countries, they consider heterogeneity between different types of firms and between different countries. The estimation of multilevel latent class models identifies groups of firms and groups of EU countries with homogeneous CE practices and attitudes. The multilevel approach also estimates the distribution of the homogeneous groups of firms across the groups of countries. Given that the demographic and business profiles of firms with similar CE attitudes may differ across European countries, our findings may shed further light on the topic of green behavior in the EU. In short, we develop a two-level taxonomy of CE strategies in firms and countries in the EU.

The paper is organized as follows. Section 2 gives an overview of CE practices in the European Union, in particular in the context of small and medium-sized enterprises. Section 3 describes the Eurobarometer surveys and the data used in the analyses. Section 4 describes the multilevel methodology that permits the identification of a taxonomy of firms and countries by latent class models. Section 5 reports the results of the proposed taxonomy with reference to our sample of European firms. Section 6 discusses the implications and concludes.

2 Circular economy

2.1 Circular economy in the European Union

As Geissdorfer et al. (2017) report, Germany was the first European country to introduce CE in the national law in 1996. Other pioneers were Japan and China where CE practices were formally adopted in 2002. In the last decade, the EU has actively promoted CE: 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 and 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). Forerunner countries such as Finland, the Netherlands, and the United Kingdom have adopted and applied national-level policies explicitly framed as circular (Repo et al., 2018). Stahel's study of seven European countries shows that a shift to a CE would

reduce each nation's greenhouse gas emissions by up to 70% and grow the workforce by about 4% (Stahel, 2016). Nevertheless, implementing CE is a challenging task given the prevalence of linear mindset strategies in industry and society. Various researchers note that environmental benefits are easier to perceive than economic benefits. Implementing CE practices often entails industries making extra investments that might not be considered profitable. It is generally believed that policy initiatives favoring CE are required worldwide. In Europe, the current rules do little to foster this market development (Dalhammar, 2016).

One of the key documents of the CE Package, the CE Action Plan, which is published every year, seeks to encourage companies to pursue a sustainable environment focusing on the entire value chain, from production to consumption, repair and remanufacturing, waste management, and secondary raw material. Special emphasis is placed on efficient use of resources and a privileged target of EU policies are SMEs since they represent over 99% of all firms operating in the territory (European Commission, 2011). The European Union Green Action Plan for SMEs[2] introduced in 2014 specifically supports green business development, setting objectives and specific actions.

2.2 Circular economy and SMEs

The European Commission defines small and medium-sized enterprises (SMEs) as those with less than 250 employees and that do not exceed 50 million euros of annual turnover, or 43 million euros of total annual balance (European Commission, 2003). In the EU, SMEs account for 99.8% of non-financial business enterprises, 66.4% of employment, and 56.8% of added value generated by the non-financial business sector, according to the Annual Report on European SMEs (European Union, 2018). At the same time, SMEs are considered responsible for around 70% of total pollution (Hogendoorn et al., 2015). Moreover, they are more active in sectors that are nearer to CE principles, such as repair, recycling and innovation. On the other hand, their small size leads to some difficulties in making applications for incentives and funding. Moreover, the big industries' knowledge of CE has not been spread sufficiently to small and medium-sized enterprises (SMEs).

[2] https://ec.europa.eu/growth/smes/business-friendly-environment/green-action-plan/

Sustainability practices in SMEs is a common topic in the literature (see, for example, Lawrence et al., 2006). Published studies suggest that firm size is an important factor in determining the extent and quality of implemented sustainability measures, that is, smaller firms undertake fewer environmental practices (Brammer and Pavelin, 2008). Other studies concentrate on internal and external barriers to sustainability for SMEs: Álvarez Jaramillo et al. (2018) provide an extensive review of the literature. According to Hoskin (2011), 70% of total air pollution is due to SMEs; therefore, they should be encouraged to be proactive in the implementation of environmental measures. This has led to specific research dealing, for example, with sustainability choices in SMEs (Siddique and Sciulli, 2017), with the determinants of these choices (Knight et al., 2017), and the relationship between implementing CE practices and firm performance (Prieto-Sandoval et al., 2017; Malesios et al., 2018). In addition, Miralles-Quiros et al. (2017) explore the impact of sustainability measures on firm value in EU markets and find a non-negligible amount of cross-country variation.

Some studies attempted to segment consumers according to their green behavior. For instance, Sarti et al. (2018) identify consumer groups that purchase sustainability and health-related labels, and find that segments depend on what type of benefits the label promises. Such results are relevant to firms that want to use sustainability to brand their products and could even encourage CE practices. Another stream of research has addressed consumers' attitudes towards green behavior. For example, Saleem et al. (2018) analyze the psychological factors that discriminate green and non-green consumers; McDonald and Oates (2003) study British consumers' attitudes towards recycling; Hanyu et al. (2000) concentrate on factors related to paper recycling in Japan; Jansson et al. (2010) focus on green consumers in Sweden; and Huang at al. (2006) analyze consumers' green behavior in China.

Few published studies analyze the segmentation of firms in terms of green behavior. One example is from Castellacci and Lie (2016), who produce a taxonomy of groups of green innovators for firms operating outside the EU. Perey et al. (2018) describe a sample of firms that changed their business model with reference to waste management; they show how these firms reframed waste as in the circular economy paradigm.

Zamfir et al. (2017) is one of the few contributions that explore the adoption of CE by SMEs across all EU member states. Their study, on the choice to adopt CE practices in European SMEs, estimates decision tree models and finds that the geographical location is the main determinant. Katz-Gerro and López Sintas (2019) calculate the probability of engaging in different CE activities, estimate patterns of interdependent activities and identify configurations of adoption as conditioned by firms' characteristics and country. Both these recent papers analyze data collected by the Flash Eurobarometer 441 survey that investigates the profile of European industries prone to CE and country level strategies, and therefore study the adoption of CE activities by SMEs across all 28 EU countries. However, they treat geographical location as a simple covariate in their models, without taking into account the hierarchical structure of the data, i.e., the fact that SMEs are nested within countries.

3 Data and methods

3.1 Eurobarometer data set

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 (e.g., use of online marketplaces and search engines by SMEs in 2016). The surveys cover citizens, households, and firms. The data set used to develop the CE taxonomy comes from the Flash Eurobarometer 441 conducted in EU countries in April 2016, involving 10,618 interviews under the supervision of the European Commission (European Commission, 2016). The respondent units are a sample of SMEs (firms with from 1 to 250 employees), operating in the economic activity sectors of manufacturing, retail, services, and industry located in the EU. The questionnaire collects information on firms, such as dimension, number of employees, amount of turnover, sector of activity, and on the implementation of CE-related activities in the last three years and intentions to adopt these practices in the near future. The 28 EU countries included in this study are listed alphabetically: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Malta, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United

Kingdom.[3] These CE actions refer to energy efficiency, waste of water, and the use of recycled materials that are among the EU policy objectives for environmental issues, more specifically to the category of making products more efficient. The other two categories are banning hazardous substances and making sure that the product is appropriately disposed of at its end-of-life stage (European Commission, 2003). These last two eco-design practices are not investigated in the survey; they would require more specific questions regarding the various regulations established for different products that could not be posed to such a heterogeneous sample of firms. The CE activities covered by the questionnaire are as follows: 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.

3.2 Sample characterization

This sample characterization is given with reference to the two groups of firms identified, namely firms that undertook some CE activity in the past three years and firms that did not undertake any of these activities.
Of the 10,618 interviewed firms, 73.18% undertook at least one of the five above-mentioned CE actions in the last three years.[4] The distribution of the number of employees in the two groups of SMEs is statistically different, indicating that the decision to undertake activities recommended by the European Union is significantly associated with the dimension: larger and older firms are more prone to adopt CE policies. In relation to dimension, Ireland has the largest proportion of medium firms (50 to 250 employees), Germany has the highest percentage of firms with between 10 and 49 employees, and Greece has the highest proportion of very small firms.

---

[3] 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 dataset. We keep the United Kingdom given its membership at the time of data collection.

[4] Table S1 in the Supplementary Material reports the characterization of the sample of firms in each country with regard to the number of employees.

In order to better understand the characteristics of the sample for these 28 countries in relation to heterogeneity at country level, we applied simple correspondence analyses to the data (Greenacre, 2016). This statistical technique summarizes the relationships between two categorical variables in a two-dimensional space.[5] Figure 1 shows the relationship between firm dimension in terms of number of employees and the adoption of CE practices across the 28 EU Member States. The first dimension (horizontal axis) accounts for 61.3% of inertia and, going from left to right, refers to the adoption of some CE activities; the second dimension (vertical axis, 34.6% of inertia) refers to firm size. In general, countries that have adjacent positioning in the map are similar. Four groups of countries can be identified, located in the four quadrants of the graphical representation. One group is composed of Bulgaria, Estonia, Denmark, Lithuania, Latvia, and Hungary, where firms have a medium size and do not, in general, implement CE activities. In Cyprus, Czech Republic, Greece, Italy, The Netherlands, Poland, Sweden, Slovenia, Slovakia, SMEs are very small and, again, are not prone to adopt CE practice. On the right side of the map, we find countries where SMEs are more sensitive to the topic of sustainability: the average size of firms is small in all of these countries with the exception of Germany.

[Figure 1 about here.]

Figure 2 refers to the relationship between the adoption of CE practices and the percentage of 2015 turnover invested in R&D.[6] Firms that invest a larger percentage of turnover in research and development are more prone to implement CE related activities (Table S2). On the right hand-side of the map, we find the countries where SMEs are on average more likely to apply CE practices, the percentage of turnover is not very high, maximum 20% in Western European territories. The majority of Eastern European countries are located on

[5] All the contingency tables used to perform correspondence analysis are given in Supplementary Material online (Tables S1, S2, S3, and S4). These tables also describe the sample of firms at the country level, i.e., they give insights into the variability between countries in terms of adoption of CE practices by firm size, percentage of turnover invested in R&D, distribution in the economic activity sectors, as well as adoption of CE practices. These figures are comparable since statistics are calculated with weighted data that take the differences in the number of firms in the various countries into account. Figures in the tables show that there is non-negligible heterogeneity between countries in terms of firms' characteristics. This heterogeneity is confirmed by the chi-square test calculated on the relationship between countries and the distribution of these categorical variables.

[6] Source data is in Supplementary Material (Table S2).

the right hand-side of the graph, indicating less attention to CE, even though the average percentage of turnover invested in R&D is high in some of them, for example, Poland and Romania. Italy, in this map, is located nearer to Eastern European than to Western countries.

[Figure 2 about here.]

Figure 3 shows the relationship between CE practices and the sector of economic activity of the SME – manufacturing, retail, services, and industry –in the 28 European countries.[7] CE practices are used slightly less in firms that provide services (Table S3). The first dimension, on the horizontal axis, accounts for 50% of total inertia and is linked to CE adoption. Sectors are represented on the vertical axis. The map shows great heterogeneity across countries in this case: two groups are clearly shown on the left hand-side; all other countries are located at a distant from each another on the right hand-side. The first homogenous group is composed of Finland, The Netherlands, Germany and Sweden, where SMEs operate mainly in services and adopt CE practices; the second is composed of Austria, Belgium, Great Britain, Spain, Ireland, Luxemburg, and Portugal, where again SMEs adopt CE practices but operate mainly in industry and manufacturing. Malta appears as an outlier country, in this case, prone to green practices with SMEs operating in all economic activity sectors.

[Figure 3 about here.]

The distribution of the sample of SMEs by the percentage of turnover invested in CE activities in the 28 EU countries[8] shows that on average, almost 35% of SMEs in the sample did not invest in CE activities in the past three years; however, there are differences across Europe. For example, the United Kingdom (47.63%) has the highest percentage of non-investing firms, followed by Sweden (45.63%) and Estonia (45.45%); on the other hand, Germany has the largest proportion of firms investing a high percentage of turnover in CE activities (11.33%). SMEs in the 28 EU countries are also differently distributed across economic activity

[7] Source data is in Supplementary Material (Table S3).

[8] Source data is in Supplementary Material (Table S4).

sectors: as an example, in Greece 50% of SMEs are active in the retail sector, in Finland this percentage decreases to 20%; in the Netherlands more than 50% of SMEs offer services, while in Eastern European countries most firms operate in industry and manufacturing. This heterogeneity in the SME profiles in the 28 European countries has an evident impact on the decision to adopt CE practices. Figure 4 (see Table S4) shows the most heterogeneous pattern in the graphical representation, considering CE implementation and the percentage of turnover invested in it. The horizontal dimension accounts for 60% of total inertia and represents, from left to right, undertaking CE activity. An expected result is that of SMEs in Croatia and Finland implement some CE practices, although they dedicate no economic resources to them.

[Figure 4 about here.]

3.3 Circular economy at the country level

Figures 5 to 9 present the percentages of adoption of CE practices at the country level. Each figure refers to one of the five CE practices that are investigated by the Flash Eurobarometer 441: 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, redesigning products and services to minimize the use of materials or use recycled materials. SMEs were asked about each of these five practices with reference to the previous three years and had to answer using four ordinal responses: no, and we do not plan to do so; no, but we plan to do so; yes, activities are underway; and yes, activities have been implemented.

[Figure 5 about here.]

[Figure 6 about here.]

[Figure 7 about here.]

[Figure 8 about here.]

[Figure 9 about here.]

By merging the information reported in the five figures using cluster analysis, it is possible to identify four homogeneous groups of countries for the percentage of SMEs operating in the territory that implemented the five CE practices or where they are at least underway. Group A with the greenest firms is composed of Austria, Belgium, Denmark, and Finland. On average, 28% of firms in these countries adopted the practice of re-planning water usage, 49% are re-planning energy usage, 73% are trying to minimize waste, 45% are redesigning products and services in order to become more ecological; these percentages are the highest over the four groups. A significant percentage of firms (17%) in these countries use renewable energy; however, a higher proportion is found in the second-ranked group, Group B, namely Estonia, the United Kingdom, Ireland, Luxemburg, Malta, and Portugal. As regards the other four CE practices, the percentages of adoption are slightly lower in Group B than in Group A, which is the most virtuous group. On the other hand, Group C is made up of the countries with the smallest proportion of SMEs adopting CE practices, that is Bulgaria, Estonia, Latvia, and Lithuania. All other countries (Group D), Cyprus, Czech Republic, France, Greece, Hungary, Croatia, Italy, the Netherlands, Poland, Sweden, Slovenia, and Slovakia show average percentages of CE adoption. Overall, waste reduction is the most adopted practice in EU SMEs and renewable energy is the least adopted. These descriptive results suggest heterogeneity in the behavior under study: CE practices are adopted with differences both within and between EU countries.

4 The multilevel latent class model

Latent class (LC) analysis provides models that specifically consider the fact that one or more latent variable is not directly observable when studying relationships between observed variables and it takes the categorical nature of these variables into account. This type of analysis was introduced by Lazarsfeld and Henry (1968) to express latent attitudinal variables from dichotomous survey items; it was then extended to nominal variables by Goodman (1974a, 1974b). Let Y_{ijk} $i = 1, \dots, I, j = 1, \dots J, k = 1, \dots K$ denote the response of firm or level-1 unit i within the country or level-2 unit j on the indicator or item k; s_k, $s_k = 1, .., S_k$, a particular level of item k; Z_{ij}, a latent variable with L classes; l, a particular latent class, $l = 1, \dots, L$; $\boldsymbol{Y}_{ij}$, the

full vector of responses of firm i in country j; $\boldsymbol{s}$, a possible response pattern. The probability structure defining a simple LC model is expressed as follows:

$$P(\boldsymbol{Y}_{ij} = \boldsymbol{s}) = \sum_{l=1}^{L} P(Z_{ij} = l) P(\boldsymbol{Y}_{ij} = \boldsymbol{s} | Z_{ij} = l) = \sum_{l=1}^{L} P(Z_{ij} = l) \prod_{k=1}^{K} P(Y_{ijk} = s_k | Z_{ij} = l) \quad (1)$$

As specified in equation (1), the probability of observing a particular response pattern is a weighted average of the class-specific probability $P(Y_{ijk} = s_k | Z_{ij} = l)$, the weight being the probability that firm i in country j belongs to latent class l. As the local independence assumption implies, indicators Y_{ijk} are assumed to be independent conditional on LC membership.

Multilevel latent class models (MLCMs) extend LC and allow the model parameters to vary across groups, clusters or level-2 units (Vermunt, 2003). As an example of hierarchical data, operations are nested in a bank's customers: operations are level-1 units, clients are level-2 units (Bassi, 2017). This is different from traditional latent class modeling, which assumes that the parameters are the same for the whole sample. The multilevel approach allows for variation across level-2 units for the intercept (threshold) of each latent class indicator. This makes it possible to examine how level-2 units influence the level-1 indicators that define latent class membership. The MLCM consists of a mixture model equation for level-1 and level-2 units, in which a group-level discrete latent variable is introduced so that the parameters are allowed to vary across latent classes of groups:

$$P(\boldsymbol{Y}_{ij} = \boldsymbol{s}) = \sum_{h=1}^{H} \left[P(W_j = h) \prod_{i=1}^{n_j} \left[\sum_{l=1}^{L} P(Z_{ij} = l \,|\boldsymbol{X}_{ij} = \boldsymbol{x}_{ij,}\, w_j = h) \prod_{k=1}^{K} P(Y_{ijk} = s_k | Z_{ij} = l) \right] \right] \quad (2)$$

where W_j denotes the latent variable at the country level, assuming value h, with $h = 1, \dots, H$; Z_{ij} the latent variable at the firm level, assuming value l, with $l = 1, \dots, L$; n_j the size of country j. Equation (2) is obtained with the additional assumption that n_j firms' responses are independent of one another conditional on country class membership. A natural extension of the MLCM involves including level-1 P covariates to predict membership (X_{ijp}), $p = 1, \dots, P$, like an extension of the LC model with concomitant variables (Dayton & McReady, 1988). In MLCM terminology, the categories of the latent variable for level-1 units are called clusters, while the categories of the latent variable for level-2 units are called classes. Thus, EU countries (level 2) are grouped into homogeneous classes given by the similarity of clusters of firms (level 1)

within countries.[9] From the estimation of $P(Z_{ij} = l \,|\boldsymbol{X}_{ij} = \boldsymbol{x}_{ij,}\, w_j = h)$ we obtain the probability that company i in country latent class h and with a set of characteristics $\boldsymbol{X}_{ij}$ belongs to latent class l. Assuming a logit-link function, the interpretation of intercepts and slopes is similar to the multinomial logit regression model.

Each country sample is representative of that country, but sample weighting is needed to ensure that countries are considered at their exact size weight at European level. For the latent class model, when weights are specified, parameters are estimated by the pseudo-likelihood method that takes the company and country weights into account (Wedel et al., 1998; Patterson et al., 2002). This research uses the weights in the Eurobarometer data set.

The estimation of the multilevel latent class model uses the implementation of the expectation-maximization (EM) algorithm (Dempster et al., 1977) proposed by Vermunt (2003). It is well-known that the log-likelihood function of mixture models contains local maxima. To minimize the impact of convergence of the algorithm to a local maximum, we run 300 models for each combination of number of classes at company and country levels from 1 to 10, i.e., 30000 runs were estimated using random starting values of the parameter estimates. The maximum likelihood solution out of the 300 runs in each combination was selected. Estimates were conducted using Latent Gold 5.0. The identification of the best number of classes at both levels is based on the BIC – Bayesian information criterion (Schwarz, 1978). We select the number of latent classes that minimizes $BIC_S = -2\ell_S + N_S \log(n)$, where ℓ_S is the log-likelihood function, N_S is the number of free parameters of the model, and n is the sample size, i.e. it takes model fit (the log-likelihood) and model complexity (number of parameters) into account. Comparing to other model selection criteria, it performs well in terms of retrieving the right model (Dias, 2006).

[9] Because of the two-level taxonomy, groups of firms and countries are referred to as clusters and (latent) classes, respectively.

5 Results

The best fitting MLCM identifies four clusters of firms and three latent classes of EU countries. This is the model with the best BIC from the set of model specifications with different combinations of the number of clusters and classes. Model fit was judged using the procedure suggested by Lukočienė et al. (2010): a significant decrease in the values of the BIC index is observed until four clusters and three classes. Increasing the number of classes and\or clusters of the MLCM produces a negligible change in the BIC statistics.[10] Thus, we did not obtain a minimum value for the BIC measure. However, after analyzing the class sizes and profiles and based on the elbow observed in the BIC values, we chose the model with three classes at country level and four at individual level.

[Table 1 about here.]

Each of the four clusters of SMEs has a different percentage of firms that adopted the five CE related activities (Table 1). Cluster 1 (26.2% of firms) is of special interest since almost no firms have adopted any of the practices under study and they are not planning to do so. In contrast, firms in Cluster 3 (24.3%) adopted or are intending to adopt almost all practices, albeit with different percentages: re-planning energy usage, minimizing waste and redesigning products are implemented or will soon be implemented by over 70% of firms. This cluster contains the most virtuous firms in terms of attention to CE. In Cluster 2, 19.5% of firms are planning to implement the five CE practices in the near future. Finally, Cluster 4 contains SMEs that are only interested in specific CE practices: they do not intend to re-plan water or energy usage or to start using renewable energy, but are inclined towards minimizing waste and redesigning products and services in order to minimize the use of materials.

[Figure 10 about here.]

[10] Results are available from the authors upon request.

Figure 10 shows which countries belong to the three latent classes, depicting posterior probabilities. The most heterogeneous group of countries is quite large and is formed by Northern, Western and Central European countries (Denmark, Finland, Sweden, Belgium, the United Kingdom, Ireland, Latvia, Luxemburg, the Netherlands, Austria, Germany, France), Portugal and Cyprus. A second latent class contains countries located in Eastern Europe (Bulgaria, Czech Republic, Estonia, Greece, Hungary, Lithuania, Poland, Romania, Slovakia, and Slovenia), plus Spain and Malta. Italy stands alone, which is a surprising result. The figures in Table 2 show that there are three groups of EU countries with four typologies of firms, each with different percentages. Firms that belong to LCs 1, 3 and 4 are present in the first group of countries. SMEs of all typologies are found in the second group of countries and in Italy, but there is an above average presence of firms in LC 2. Thus, the relationship between the three clusters of EU countries and the four classes of SMEs is relevant to policy implementation. Specifically, they clearly underline the European policies favoring the implementation of CE practices that should be targeted at least for subgroups of European countries, considering the different composition by typology of SMEs operating in their territories. At the same time, within each group of countries, policies should be defined to account for the specific features of each of the four classes of SMEs. The main message is that general policies for all 28 EU Member States and all types of SMEs have no chance of succeeding.

[Table 2 about here.]

In general, there is a non-negligible heterogeneity across EU countries, which means that firms with a favorable attitude towards CE are not concentrated in specific countries. However, whereas the first group of Scandinavian, Western, and Northern countries with Cyprus and Portugal is characterized by the absence of firms planning to introduce CE practices, this type of firm prevails in the other two groups. Italy has a high prevalence of firms that intend to implement CE practices in the near future.

The variables used as indicators are all statistically significant and discriminate the four classes of SMEs that show non-negligible differences in the analyzed characteristics. Tables S5, S6, and S7 in Supplementary Material contain the typical profile of firms in the four classes within each of the three groups of European

countries, with reference to the variables used in the MLCM as covariates (X_{ijp}). Table S5 refers to SMEs located in the first group of EU countries; model estimates show that the four clusters of firms based on their attitudes towards CE do not have significantly different demographic characteristics such as dimension, age, total turnover, and percentage of turnover invested in R&D. The only relevant evidence is that involvement in administrative and support service activities has a negative significant effect in the class of firms planning to introduce CE practices, and there is a very small percentage of these firms in these countries. In contrast, firms classified in the four classes in the second group of European countries (Table S6) show significant differences in age, type of product or service being sold, and sector of economic activity. Specifically, in clusters 2, 3, and 4, older firms and firms selling services to consumers have a negative impact on the advancement of CE practices, whereas this effect is positive in the case of services sold to firms or other organizations. Country-level latent class 3 (Italian firms) is very unusual (Table S7): firms in the four classes differ in terms of dimension, age, total turnover, and type of business. In latent class 3, the attitude and practices of CE are negatively affected by age, but positively affected by the percentage of turnover invested in R&D.

6 Discussion and concluding remarks

This article provides a taxonomy of EU firms regarding their implementation of CE practices. Although there has been an increase in environmental policies in the EU, their adoption by firms varies across countries. This is particularly true for small and medium enterprises (SMEs) as large firms have already developed their CE knowledge and practices. However, SMEs, which are the focus of this study, represent the large majority of business units in Europe; moreover, they are responsible for a large proportion of waste and pollution. It is important to have a greater understanding of the factors that affect SMEs' decision to favor sustainability. This paper contributes to this research topic by analyzing European Commission data within the Eurobarometer framework, more specifically, the Flash Eurobarometer 441 survey using a sample of over 10,000 firms distributed across all 28 EU countries. Firms with different sizes, ages, and types of

activity were asked to report on five main CE practices: re-planning water and energy usage, using renewable energy, minimizing waste, and redesigning products.

This research disentangles country and company effects regarding CE practices for the first time by proposing a dual typology. We estimate a multilevel latent class model in order to identify groups of EU SMEs with homogeneous intentions on CE practices and also groups of countries that are homogeneous in the composition of firms operating in their territory. Firms are classified into four classes: companies with no interest in CE, that do not adopt or plan to adopt CE practices; companies in the process of introducing CE (the smallest group); firms interested in specific CE practices only, e.g. minimizing waste and redesigning products to use recycled materials (the largest group); and firms with a very positive attitude towards the green economy that already implement the CE practices analyzed. Model estimation results identify three classes of European countries: Scandinavian, Western and Northern countries plus Cyprus and Portugal; Eastern European countries plus Spain and Malta; and a third cluster that singles out Italy. All four types of firms operate in these three groups, but with different degrees of interaction with CE activities: the percentage of firms with activities underway is negligible in the first group, but this is the prevailing typology in the other two groups.

Our research presents a picture of SMEs' involvement in CE activities across the EU. It suggests that the decision to favor CE behavior is closely linked to dimension, both in terms of employees and turnover, and the sector of economic activity. The percentage and types of firms that adhere to CE practices are very heterogeneous across EU countries, which indicates that EU policies should be differentiated accordingly.

Rather than a multigroup approach that is more focused on measurement and confirmatory issues, we took a multilevel latent class approach. This exploratory analysis is flexible in that we wanted to find the best configuration of companies and EU countries regarding the CE practices. As a result of the weight system, individual country analyses do not provide insights as the solution has to be a compromise at the 28-country level. Nevertheless, large countries that are too heterogeneous (between-country heterogeneity), such as Italy, have enough weight to force an extra latent class at country level.

Future research lines arising from this paper include an analysis of what differentiates the three groups of EU countries, introducing country-level covariates such as social and economic variables, in order to evaluate

their impact on the willingness to implement CE practices. This study also shows that Italy does not fall into the dichotomy of countries. More specific studies can explore the sample for this country and identify specific patterns regarding the Italian CE practices using the EU sample as a benchmark. These results also support the hypothesis of a natural sequence in the implementation of these CE practices introduced by Katz-Gero and López-Sintas (2019). Further analyses can be conducted using factorial models to test these hypotheses in the multilevel context.

References

Álvarez Jaramillo, J., Zartha Sossa, J.W., & Orozco Mendoza, G.L. (2018). Barriers to sustainability for small and medium enterprises in the framework of sustainable development—Literature review. Business Strategy and the Environment, 28(4), 512-524. doi: 10.1002/bse.2261.

Bassi, F. (2017). Longitudinal models for dynamic segmentation in financial markets. International Journal of Bank Marketing, 35(3), 431-446. doi: 10.1108/IJBM-05-2016-0068.

Brammer, R.G., & Pavelin, S. (2008). Factors influencing the quality of corporate environmental disclosure. Business Strategy and the Environment, 17(2), 120-136. doi: 10.1002/bse.506.

Castellacci, F., & Lie, C.M. (2016). A taxonomy of green innovators: empirical evidence from South Korea. Journal of Cleaner Production, 143, 1036-1047. doi:10.1016/j.jclepro.2016.12.016.

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

Dayton, C. M., & McReady, G. B. (1988). Concomitant-variable latent-class models, Journal of American Statistical Association, 83, 173-178. doi: 10.2307/2288938.

Dempster, A. P., Laird, N. M., & Rubin, D. B. (1977). Maximum likelihood from incomplete data via the EM algorithm, Journal of the Royal Statistical Society - Series B Methodological, 39(1), 1-38. Doi: 10.1111/j.2517-6161.1977.tb01600.x

Dias, J. G. (2006). Latent class analysis and model selection. In M. Spiliopoulou, R. Kruse, C. Borgelt, A. Nürnberger, & W. Gaul (Eds.), From data and informationanalysis to knowledge engineering (pp. 95–102). Berlin: Springer-Verlag.

Ehrenfeld, J. (2004). Can industrial ecology be the science of sustainability? Journal of Industrial Ecology, 8, 1-3.

Ellen MacArthur Foundation (2015). Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition, Isle of Wight. Available on: https://www.ellenmacarthurfoundation.org/assets/downloads/TCE_Ellen-MacArthur-Foundation_9-Dec-2015.pdf (accessed on 14.04.2019)

European Commission (2003). Communication on Integrated Product Policy Building on Environmental Life-Cycle Thinking. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52003DC0302 (accessed on 28.04.2019).

European Commission (2011). Minimizing Regulatory Burden for SMEs. Adapting EU Regulation to the Needs of Micro-Enterprises; COM 803 Final; European Commission: Brussels.

European Commission (2014). Towards a Circular Economy: a Zero Waste Program for Europe. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014DC0398R%2801%29 (accessed on 23.03.2019).

European Commission (2015). Closing the Loop - an EU Action Plan for the Circular Economy, 614 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. European Commission, Brussels. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614 (accessed on 12.04.2019).

European Commission (2016). European SMEs and the Circular Economy (Flash Eurobarometer 411). Brussels, April.

European Union (2018). Annual report on European SMEs 2017/18. Available: https://publications.europa.eu/en/publication-detail/-/publication/a435b6ed-e888-11e8-b690-01aa75ed71a1/language-en (accessed on 11.04.2019).

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

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

Goodman, L.A. (1974a). The analysis of systems of qualitative variables when some of the variables are unobservable: Part I. A modified latent structure approach. American Journal of Sociology, 79, 1179-1259. doi: 10.1086/225676.

Goodman, L.A. (1974b). Exploratory latent structure analysis using both identifiable and unidentifiable models. Biometrika, 61, 215-231. doi: 10.1093/biomet/61.2.215.

Hanyu, K., Kishino, H., Yamashita, H., & Hayashi, C. (2000). Linkage between recycling and consumption: a case of toilet paper in Japan. Resources, Conservation & Recycling, 30, 177-199. doi: 10.1016/S0921-3449(00)00060-4.

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

Hoskin, P. (2011). Why business needs to green the supply chain? University of Auckland Business Review, 84, 27-33.

Huang, P.S., Zhang, X.L., & Deng, X.D. (2006). Survey and analysis of public environmental awareness and performance in Ningbo, China: A case study on household electrical and electronic equipment. Journal of Cleaner Production, 14, 1635-1643. doi: 10.1016/j.jclepro.2006.02.006.

Hughes, R. (2017). The EU Circular Economy package - life cycle thinking to life cycle law?, 24th CIRP Conference on Life Cycle Engineering, Procedia CIRP, 61, 10-16. doi: 10.1016/j.procir.2016.12.006.

Jansson, J., Marell, A., & Nordlund, A. (2010). Green consumer behavior: determinants of curtailment and eco-innovation adoption. Journal of Consumer Marketing 27(4), 358-370. doi: 10.1108/07363761011052396.

Katz-Gerro, T., & López Sintas, J. (2019). Mapping circular economy activities in the European Union: patterns of implementation and their correlates in small and medium-sized enterprises. Business Strategy and the Environment, 28, 485-496. doi: 10.1002/bse.2259.

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

Knight, K.W., Schor, J. B., & Jorgenson, A.K. (2017). Wealth inequality and carbon emissions in high-income countries, Social Currents, 5, 403-412. doi: 10.117/2329496517704872.

Korhonen, J., Honkasalo, A., & Seppala, J. (2018). Circular economy: The concept and its limitations. Ecological Economy, 143, 37-46. doi: 10.1016/j.ecolecon.2017.06.041

Lawrence, S.R., Collins, E., Pavlovich, K., & Arunachalam, M. (2006). Sustainability practices of SMEs: the case of NZ. Business Strategy and the Environment, 15(4), 242-257. doi: 10.1002/bse.533.

Lazarsfeld, P.F. & Henry, N.W. (1968). *Latent Structure Analysis*. Boston, Houghton Mifflin.

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: A comprehensive review in context of manufacturing industry. Journal of Cleaner Production, 115, 36-51. doi: 10.1016/j.jclepro.2015.12.042.

Liu, L., Liang, Y., Song, Q., & Li, J. (2017). A review of waste prevention thorough 3R under the concept of circular economy in China. Journal of Material Cycles and Waste Management, 19, 1314-1323. doi: 10.1007/s10163-017-0606-4.

Liu, Q., Li, H., Zuo, X., Zhang, F., & Wang, L. (2009). A survey and analysis on public awareness and performance for promoting circular economy in China: A case study from Tianjin. Journal of Cleaner Production, 17, 265-270. doi: 10.1016/j.jclepro.2008.06.003.

Lukočienė, O., Varriale, R. and Vermunt, J.K. (2010). The simultaneous decision(s) about the number of lower- and higher-level classes in multilevel latent class analysis, Sociological Methodology, 40, 247-283. doi: 10.1177/0013164415618240.

Malesios, C., Skouloudis, A., Dey, P. K., Abdelaziz, F. B., Kantartzis, A., & Evangelinos, K. (2018). Impact of small- and medium-sized enterprises sustainability practices and performance on economic growth

from a managerial perspective: Modeling considerations and empirical analysis results. Business Strategy and the Environment, 27, 960-972. doi: 10.1002/bse.2045.

McDonald, S., & Oates, C. (2003). Reasons for non-participation in a curbside recycling scheme. Resources, Conservation & Recycling, 39, 369-385. doi: 10.1016/S0921-3449(03)0020-X.

McDonough, W., & Braungart, M. (2002). *Cradle to Cradle: Remaking the Way We Make Things*, North Point Press, New York.

Miralles-Quiros, M., Miralles-Quiros, J.L., & Arriano, I.G. (2017). Sustainable development, sustainability leadership, and firm valuation: differences across Europe. Business Strategy and the Environment, 26, 1014-1028. doi: 10.1002/bse.1964.

Patterson, B. H., Dayton, C. M., & Graubard, B. (2002). Latent class analysis of complex sample survey data: Application to dietary data (with discussion). Journal of the American Statistical Association, 97(459), 721–741. doi: 10.1198/016214502388618465.

Pauli, G. (2010). *The Blue Economy*, Paradigm Publication, Boulder (CO).

Perey, R., Benn, S., Agarwal, R., & Edwards, M. (2018). The place of waste: Changing business value for the circular economy. Business Strategy and the Environment, 27(5), 631-642. doi: 10.1002/bse.2068

Prieto-Sandoval, V., Ormazabal, M., Jaca, C., & Viles, E. (2017). Key elements in assessing circular economy implementation in small and medium-sized enterprises. Business Strategy and the Environment, 27, 1525-1534. doi: 10.1002/bse.2210.

Repo, P., Anttonen, M., Mykkanen, J., & Lammi, M. (2018). Lack of congruence between European citizen perspectives and policies on circular economy. European Journal of Sustainable Development, 7(1), 249-264. doi: 10.14207/ejsd.2018.v7n1p249.

Saleem, M., Eagle, L., & Low, D. (2018). Market segmentation based on eco-socially conscious consumers' behavioral intentions: evidence from an emerging economy. Journal of Cleaner Production, 193, 14-27. doi: 10.1016/j.jclepro.2018.05.067.

Sarti, S., Darnall, N., & Testa, F. (2018). Market segmentation of consumers based on their actual sustainability and health-related purchases. Journal of Cleaner Production, 192, 270-280. doi: 10.1016/j.jclepro.2018.04.188.

Siddique, S.P., & Sciulli, N. (2017). Sustainable development of small companies: investors' perspectives. Business Strategy and the Environment, 27, 1258-1271. doi: 10.1002/bse.2073.

Stahel, W.R. (1982). The product-life factor. In NARC, Hrsg. An Inquiry into the Nature of Sustainable Societies: The Role of the Private Sector. s.l.:1982 Mitchell Prize Papers, 72–96.

Stahel, W.R. (2016). Circular economy. Nature, 531, 453-438. doi: 10.1038/531435a.

Van, Q. L., Nguyen, T. V., & Nguyen, M. H. (2019). Sustainable development and environmental policy: The engagement of stakeholders in green products in Vietnam. Business Strategy and the Environment, 28(5), 675-687. doi: 10.1002/bse.2272.

Vermunt J.K (2003). Multilevel latent class models. Sociological Methodology, 33(1), 213-239. doi: 10.1111/j.0081-1750.2003.t01-1-00131.x.

Wedel, M., ter Hofstede, F., & Steenkamp, J. (1998). Mixture model analysis of complex samples. Journal of Classification, 15(2), 225–244. doi: 10.1007/s003579900032.

Westman, L., Luederitz, C., Kundurpi, A., Mercado, A.J., Weber, O., & Burch, S.L. (2018). Conceptualizing businesses as social actors: A framework for understanding sustainability actions in small and medium sized enterprises. Business Strategy and the Environment, 28(2), 388-402. doi: 10.1002/bse.2256.

Wong, G.Y., & Mason, W.M (1985). Hierarchical logistic models for multilevel analysis. Journal of the American Statistical Association, 80, 513-524. doi: 10.2307/2288464.

Zamfir, A., Mocanu, C., & Girgorescu, A. (2017). Circular economy and decision models among European SMEs. Sustainability, 9, 1507. doi: 10.3390/su909150.

Tables

Table 1. CE practices within firm-level clusters

	Clusters (firm level)				Overall
	1: no CE	2: planning to	3: all CE	4: specific CE	
Cluster size	0.262	0.195	0.243	0.300	
Re-planning the way water is used to minimize usage and maximize re-usage (in the last 3 years)?					
No, and we do not plan to do so	0.964	0.489	0.479	0.894	0.732
No, but we plan to do so	0.036	0.201	0.095	0.005	0.073
Yes, activities are underway	0	0.280	0.036	0.027	0.071
Yes, activities have been implemented	0	0.030	0.390	0.075	0.123
Use of renewable energy (in the last 3 years)?					
No, and we do not plan to do so	0.937	0.500	0.418	0.857	0.702
No, but we plan to do so	0.063	0.311	0.200	0.031	0.135
Yes, activities are underway	0	0.154	0.048	0.047	0.056
Yes, activities have been implemented	0	0.035	0.333	0.065	0.107
Re-planning energy usage to minimize consumption (in the last 3 years)?					
No, and we do not plan to do so	0.900	0.199	0.141	0.599	0.488
No, but we plan to do so	0.100	0.267	0.152	0.041	0.127
Yes, activities are underway	0	0.449	0.092	0.107	0.142
Yes, activities have been implemented	0	0.086	0.616	0.253	0.242
Minimizing waste by recycling or reusing waste or selling it to another company (in the last 3 years)?					
No, and we do not plan to do so	0.937	0.156	0.147	0.265	0.391
No, but we plan to do so	0.063	0.121	0.044	0.003	0.052
Yes, activities are underway	0	0.608	0.048	0.220	0.196
Yes, activities have been implemented	0	0.115	0.761	0.511	0.361
Redesigning products and services to minimize the use of materials or using recycled materials (in the last 3 years)?					
No, and we do not plan to do so	0.938	0.313	0.249	0.616	0.552
No, but we plan to do so	0.062	0.219	0.102	0.031	0.093
Yes, activities are underway	0	0.419	0.090	0.113	0.137
Yes, activities have been implemented	0	0.050	0.559	0.240	0.218

Table 2. Distribution of firm-level clusters within country-level classes

Clusters (firm level)	Latent classes (country level)			Overall
	1	2	3	
1	0.266	0.261	0.234	0.262
2	0.075	0.306	0.366	0.195
3	0.340	0.141	0.232	0.243
4	0.319	0.292	0.169	0.300