Barriers to the circular economy in European small and medium-sized firms[1]

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Abstract: The concept of the circular economy (CE) is currently gaining impetus as a way to move towards sustainable, low carbon, resource efficient and competitive economies. However, despite the potential benefits of CE activities, their implementation remains relatively rare. We use a cross-sectional survey of European SMEs to identify the main barriers firms face to promote the CE, focusing specifically on the following: those related to a lack of resources (human and financial) and capabilities (expertise), and those related to the regulatory framework (administrative procedures and the costs of meeting the regulations). Our results indicate that it is the complexity of administrative/legal procedures and the costs of meeting regulations/legal standards that constitute the most significant barriers, while the lack of human resources is also perceived to be an obstacle by firms engaged in CE activities. Those obstacles may be considered revealed barriers and it is only when the firms become involved in these activities that they actually perceive them. Furthermore, when we consider the breadth of CE activities, administrative procedures and regulations once again emerge as the most significant obstacles. Finally, we stress the need to distinguish between different CE activities given that the perception of barriers differs substantially across these activities. Firms undertaking a disruptive innovation redesigning products and services to minimize the use of materials are more likely to perceive all barriers as important. However, firms implementing such activities as minimizing waste, re-planning energy usage and using renewable energy only perceive those obstacles related to administrative procedures and regulations.

Keywords: Green innovation, circular economy, barriers, SMES, decision models

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1. Introduction

The world is being exposed to profound changes, not least as regards its attempts to move towards sustainability. The world's population is growing constantly and by 2040 it is projected to reach 9.2 billion, up from today's 7.4 billion (International Energy Agency, 2018). In parallel, this growth will inevitably lead to massive increases in the demand for natural resources, reaching levels greater than the rate at which they can be replaced. At the same time, greenhouse gas emissions, the chief culprit for climate change, continue to increase. Against this backdrop, there is a pressing need to change the way that citizens, firms and governments interact with the environment. Given the limitations of the conventional linear economy based on its "take, make, use and waste" sequence, the concept of a circular economy (CE) is gaining impetus as a means of moving towards sustainable, low carbon, resource efficient and competitive economies. However, this transition from a linear to a circular model of production and consumption will only be possible if adequate policies are in place within an enabling framework that stimulates innovation and technological development (De Jesus et al., 2018). First, in December 2015 and then, later, in January 2018 the European Commission launched a set of legislative proposals to guide European firms and consumers towards the implementation of the CE (European Commission 2015, 2018a).[2]

It is predicted that among the benefits of promoting the CE, we should witness an increase in the EU's competitiveness, the proliferation of new business opportunities and the creation of local jobs that can boost social integration and cohesion. At the same time, it should deliver major energy savings and considerable environmental benefits (Ellen MacArthur Foundation 2015). In this sense, the CE is closely linked to some of the EU's most pressing needs as regards jobs and growth, investment, innovation, climate and energy. Indeed, such is its potential that it has been recognized as a key strategic priority in meeting the Paris Agreement temperature objectives for the transition to a net-zero greenhouse gas emissions economy by mid-century (European Commission 2018b).

Although there seems to be an appreciable awareness of the benefits of the CE and substantial public support for such an economy, implementation remains in its early stages with progress being slow and neither widespread nor uniform (Kirchherr et al., 2018). The adoption of CE practices means having to overcome a variety of barriers and challenges in line, that is, with each firm's strategy, resources and capabilities. This is especially true of small and medium-sized firms (SMEs), given that they typically face greater constraints with regard to the availability of resources than those faced by larger firms (Ghisetti et al., 2016; Ormazabal et al., 2018). This means that being able to identifying the factors hindering entrepreneurs' decisions to implement CE practices should help policy-makers promote the instruments needed to overcome these barriers. However, to date, data constraints have substantially limited empirical analyses of the barriers to the CE to theoretical and conceptual frameworks and case studies (Govindan and Hasanagic 2018) and, as De Jesus and Mendonça (2018) have recently highlighted, more empirical evidence in relation to these barriers is still required.

[2] The European Commission implemented an ambitious Circular Economy Action Plan which includes 54 specific actions covering the whole cycle, from production and consumption to waste management and the market for secondary raw materials, a revised legislative proposal on waste, and a strategy for reducing plastics among others. For more detailed information see: https://ec.europa.eu/environment/circular-economy/

To fill this gap, in the present study, we seek to provide an empirical answer to the following research question: What barriers do firms perceive to their engaging in or developing circular economy activities? To do so, we use the European Commission's Eurobarometer Survey 441, which provides the opportunity to study a set of barriers related to the regulatory framework (that is, administrative procedures and the costs of meeting regulations), and to the lack of resources (human and financial) and capabilities (expertise). According to this survey, CE activities are understood as any activity related to the way water is used to minimize usage, the use of renewable energy, the re-planning of energy usage to minimize consumption, the minimization of waste and the redesigning of products and services to minimize the use of materials.[3]

By applying a multivariate probit model instead of univariate probit models to 10,098 European SMEs, we account for a certain correlation between errors due to the relationship of firms' perceiving more than one barrier jointly. Our results show that barriers related to the existing regulatory framework are the most important; moreover, the lack of human resources is also perceived as an obstacle by firms engaged in the CE. When considering the breadth of CE activities, we conclude that being engaged in more than one CE activity has effects on a firm's perception of financial obstacles. Additionally, the results of our estimations show that a lack of expertise in implementing CE activities deters firms from engaging in them. Yet, it appears there is a learning effect and when a firm becomes engaged in more than one CE activity this obstacle loses importance. Finally, our empirical results identify a need to differentiate between different CE activities since the perception of barriers differs substantially across them.

This study makes several contributions. First, the literature to date has been particularly reliant on the Chinese context[4] rather than on other geographical contexts. Since the European Commission has recently adopted new, encouraging CE policies, we consider the case of the European Union for this analysis. Specifically, we focus on the barriers that hinder SMEs, which represent 99% of European firms and account for more than two-thirds of employment. Second, the most common research methods are case studies or econometric analyses, based primarily on small samples. Here, we work with a large dataset of more than 10,000 firms. And finally, we consider not only the engagement but also the intensity with which firms engage in CE activities (number of activities) and the type of CE activities. All in all, this provides interesting results that make a sizeable contribution to the empirical literature.

The remainder of the paper is structured as follows. Section 2 consists of a literature review. Section 3 presents the database and the econometric methodology. Section 4 shows our main findings. The last section presents our conclusions and some policy recommendations.

2. Background literature and research questions

Interest in the CE in academic research first emerged around 2006, but the number of publications has risen significantly since 2015. The fact that the research in this field is still in its infancy means that the CE is still a somewhat underspecified notion, laborious to define and encompassing a range of diverse areas. Indeed, defining the concept of the CE, sometimes referred to as a "closed

[3] Other papers have used this European database (Zamfir et al., 2017; Demirel and Danisman, 2019), but with different methodologies and aims to those employed and identified, respectively, in this paper.
[4] China has been at the forefront of CE studies, being one of the first countries to implement legislation on the CE (Circular Economy Promotion Law of the People's Republic of China, 2008).

loop economy", is not a simple task and several definitions co-exist in the literature (see, for example, De Jesus and Mendonça, 2018; Ghisellini et al., 2016; Zamfir et al., 2017; Govindan and Hasanagic 2018; Blomsma and Brennan, 2017; EIO, 2016; Geissdoerfer et al., 2017; Kirchherr et al., 2018; Geissdoerfer et al., 2017; Korhonen et al., 2018).

According to the European Union, broadly speaking, the CE can be understood as a way to create new business opportunities and innovative, more efficient ways of producing and consuming among several key agents, including governments, business, NGOs, consumers, citizens, academic and research centres (European Commission, 2015). More specifically, the CE represents a new system of production based on the "reduction, reuse and recycling" of raw materials. As Ghisetti and Montresor (2019) claimed, CE practices represent a particular case of environmental innovation, with similar enablers and barriers. Here, we specifically consider the following practices: The re-planning of the way water is used to minimize usage and maximize re-usage; the use of renewable energy; the re-planning of energy usage to minimize consumption; the minimization of waste by recycling and reusing waste or selling it to another company; and the redesigning of products and services to minimize the use of materials or using recycled materials.

As many authors have pointed out, the CE can be considered a new business model in which the traditional model of production, consumption and disposal is transformed into a production loop characterized by recycling and waste integration processes and in which renewable and energy efficiency are key, as is the production of redesigned products and services aimed at minimizing the use of materials (Feng and Nailing 2007; Ghisetti et al., 2016; Naustdalslid 2004). Acceptance of this new model requires changing the mentality of companies with regards to their involvement in CE activities and their taking steps towards creating a sustainable world. CE practices entail not only the use of resources and capabilities to develop new procedures of recycling and waste management but also the adoption of green innovations, including the re-planning of energy and water use. At a higher level, companies can eventually engage in the task of re-designing their products or services so as to be more proactive in the implementation of the CE. Ultimately, re-designing contributes to closing the production loop by facilitating recycling and the reintegration of products into the economic system. It has been estimated that re-design, waste prevention and reuse can produce net savings for EU enterprises of up to EUR 600 billion and a 48% reduction in gas emissions. An increase in resource productivity of 30% by 2030, would translate into an increase of 1% in GDP and the creation of 2 million new jobs (European Commission, 2015).

However, Demirel and Danisman (2019) present empirical evidence that only re-design innovation exerts a positive impact on the growth of SMEs, while other types of environmental innovation activity do not drive firm growth. Zamfir et al. (2017), using a sample of European SMEs, show that the most important factors influencing the decision of companies to adopt CE practices are the country in which they operate, the sector activity and the level of investment in R&D. In most European countries, SMEs represent the majority of business companies (99.8% according to Eurostat's Structural Business Statistics Database). This means that the determination to sustain, and to implement operations promoting the transition to more sustainable activities, plays a crucial role in their economies. To achieve these objectives, however, SMEs need to build capacities and abilities within their own boundaries using R&D investment.

The adoption of CE practices is not straightforward since it entails tangible and intangible resources to re-adapt production process activities and to transform traditional production

methods. Therefore, the adoption of various types of CE activity can also be considered to be subject to perceptions of different barriers as well as the fact that their introduction requires greater resources and implies additional costs to firms, which could colour their perception of the barriers to implementing the CE. Although the benefits of introducing CE activities, such as cost savings, reduction of CO_2 emissions, economic growth and job creation, are being increasingly recognised (Ellen MacArthur Foundation, 2012), there are still many barriers to the transition to a CE. A firm that was established in the linear economy requires time to modify the way it produces and does business and advances towards the CE. As De Jesus et al. (2018) pointed out, one of the main drivers to achieving this transformation is innovation.

The perception of barriers and the impact of these perceptions on investment decisions and the behaviour of firms have been given careful consideration in the innovation literature. Studies have typically adhered to the taxonomy of factors hampering innovation activities proposed in the Organisation for Economic Co-operation and Development (OECD) Oslo Manual, which distinguishes between four groups of barrier: cost factors; knowledge factors – lack of qualified personnel or lack of information on technology; market factors; and institutional factors – legislation, regulation or weakness of property rights. A significant number of studies have examined the obstacles that might deter or hamper firms' innovation activities (Blanchard et al., 2013; D'Este et al., 2012; García-Quevedo et al., 2018; Pellegrino and Savona, 2017). Other analyses specifically examine the factors that explain a firms' perceptions of barriers to innovation (Iammarino et al., 2009) and the effects of these obstacles on innovation (Canepa and Stoneman 2008; Savignac 2008). Although most of these studies focus on the effect of financial barriers, recent research has shown that other barriers to innovation are also important (see, for example, Blanchard et al., 2013; Hölzl and Janger, 2014; Mohnen et al., 2008; Pellegrino and Savona, 2017).

Thus, while various studies have examined the effect of barriers to technological innovation, they do not specifically address barriers to environmental innovation (EI)[5] or the CE (Blanchard et al., 2013; Hyytinen and Toivanen, 2005; Mohnen et al., 2008; Mohnen and Röller, 2005; Segarra-Blasco et al., 2008). Indeed, the literature on barriers to EI is scarce (Ghisetti et al., 2016; Marin et al., 2015), but among these studies, we can identify a group of barriers that appear to be common to them all: namely, risk and finance, knowledge and skills, market and regulation. Moreover, De Jesus et al. (2018) call for the need to develop "systemic" EI that includes technological abilities, service innovations and novel organizational set-ups. Finally, in a recent study, Arranz et al. (2019) develop a model that separates incentives from inhibiting factors in the eco-innovation process, and find that while public funding facilitates EI, costs and financing, market uncertainty and the lack of information on technology hinder the adoption of eco-innovations.

Based on the evidence presented in the literature, here, we specifically address two sets of barrier: i) the lack of resources – human and financial – and capabilities – expertise; and ii) the presence of regulations and complex administrative requirements.

CE barriers, however, are largely subjective in nature, being based primarily on personal appreciations and judgments. This subjectivity requires understanding the phenomena from the

[5] The terms environmental innovation, eco-innovation and green innovation, henceforth, are used interchangeably, each being indicative of an innovation with a lower detrimental impact on the environment.

perspective of an entrepreneur's personal knowledge and of the resources and dynamic capabilities built into every firm. Accordingly, each firm tends to implement different CE activities and to perceive different barriers. Here, given our interest in determining managerial perceptions of the barriers faced, we use subjectivist entrepreneurial theory (Penrose, 1959), in which the economic importance of an entrepreneur's personal knowledge is stressed (Polanyi, 1962), from what is an intrinsically subjective perspective (Kor et al., 2007). By adopting Kor et al. (2007) and Penrose's (1959) theories, several productive opportunity sets are produced – including innovation – to capture the perceptions and personal knowledge of entrepreneurs in order to identify the factors that deter SMEs from adopting environmental innovations. By taking such an approach, we are able to understand the different subjective perceptions of business opportunities and the way in which tangible and intangible resources and capabilities can be used to achieve a real transformation.

Lack of resources and capabilities

According to its technological capabilities and knowledge and resource base, each firm will seek to design its own specific sustainable strategies (Sáez-Martínez et al., 2016). In keeping with this argument, a resource-based view (RBV) of the firm (Wernerfelt, 1984) highlights the importance of a firm's internal resources. Likewise, Rumelt (1984) proposed that a firm's competitive advantage consists basically in the use of a set of available resources. Demirel and Danisman (2019) identified the existence of a significant threshold investment for SMEs (more than 10% of revenues) if they are to be effective in their implementation of CE activities. For firms of this size, only equity financing contributes to positive growth. Aranda-Usón et al. (2019) seek to link the use of financial resources (that is, the employment of different sources of funding) with the adoption of CE activities and show that the level of investment is closely related to the CE scope. Indeed, the lack of funding is one common obstacle that firms acknowledge as causing them not to engage in the CE.

Physical, human and financial resources all foster technology push; hence, the availability or the lack of resources and the capacity to innovate condition a firm's propensity to innovate. In this regard, knowledge resources, human skills, provision, and access to finance are essential drivers of green innovation and the CE. The lack or scarcity of adequate human resources or expertise for developing CE activities is a clear obstacle to engaging in them. Indeed, a firm's ability to recognize and exploit new resource efficiency opportunities is traditionally linked to its resources and capabilities and to the pool of knowledge available within the firm (Cainelli et al., 2012; Horbach et al., 2012; Triguero et al., 2013). Horbach (2008) and Arranz et al. (2019) confirm that having financial resources helps in the development of those innovation activities that reduce the impact on the environment. In the specific case of the adoption of CE activities, Rizos et al. (2016) highlight two main barriers for SMEs in this transition: the lack of financial resources and the lack of technical skills, with the former being especially difficult for SMEs to overcome since their non-availability of internal funds combines with the high costs of having to go to the financial markets.

Although some progress has been made in the literature using the RBV theory as a potential explanatory variable of engagement in the CE (Del Río et al., 2016), some aspects of the debate are still open to clarification. A firm's resources (internal conditions) and capabilities (strategies) are the main elements facilitating CE activities and their unavailability can result in the firm limiting its commitment to the development and engagement in CE practices.

Regulations and costly administrative requirements

As with other types of innovation, eco-innovations produce benefits for society rather than solely for the adopter of these new technologies (Carrión-Flores and Innes 2010; Costa-Campi et al., 2017). In this line, since the thesis first proposed by Porter and van der Linde (1995), the role of regulation in fostering the adoption of green technologies has been widely accepted (Carrión-Flores et al., 2013; Nesta et al., 2014) and, in common with most discussions of the Porter hypothesis, regulation emerges as a key tool for overcoming the typical market failures associated with innovation. In the case of eco-innovation, the "double externality" effect applies. As Porter and van der Linde (1995) claim, environmental regulations provide firms with greater opportunities, which, in turn, are accompanied by expansion and an increase in employment. Moreover, polluting firms can benefit from environmental policies, provided that well-designed, stringent environmental regulations stimulate innovation. Thus, regulation enters into the debate as a major barrier or driving force in the movement towards the introduction of new CE models (Milios, 2018; Pheifer, 2017; van Eijk, 2015).

According to De Jesus and Mendonça (2018), regulatory barriers are the second most pressing barrier to the CE. Indeed, the failure to adopt a strict, coherent legislative framework often impedes SMEs from integrating green solutions into their operations. Moreover, circular business models are frequently influenced by low taxes on resources that incentivize companies to purchase cheaper raw materials instead of recycled or re-designed resources, which typically incur higher production costs (Rizos et al., 2016). According to van Eijk, (2015), adjustments to the regulations may frustrate CE business initiatives, while Kirchher et al. (2018) identify four types of barrier and highlight the need to consider the interrelations between them, since, in practice, most barriers affect the transition to the CE. As these authors stress, a market barrier such as high upfront investment costs could be determined by limited circular procurement by governments, which constitutes a clear regulatory barrier. Finally, the administrative burden that the green business transition entails (the monitoring and reporting of data, for instance) represents a significant cost to companies in general but even more so for SMEs, since they cannot afford to run specific departments to deal with the complexity of rules or to hire administrative staff to oversee such processes.

The evidence from the previous literature, as described above, highlights the fact that approaches to the study of the CE vary considerably but, nevertheless, it enables us to develop a framework for the empirical analysis we conduct here. In fact, this review of recent works analysing the barriers to the implementation of the CE demonstrates that most papers employ either theoretical frameworks or case studies but that few use an econometric methodology. Yet, we are able to draw a number of general conclusions regarding the strength of the relationship – and causality – between different variables. In fact, studies of this type are almost non-existent, but, see, for example Rizos et al., (2016, 2015), Ormazabal et al., (2018), Kirchnerr et al., (2018) and, Govindan and Hasanagic (2018). Interestingly, D'Este et al. (2012) distinguished two types of perceived barrier to the implementation of innovation activities: revealed and deterring barriers. Our analysis uses this approach and we distinguish between firms that become aware of problems – revealed barriers – as they begin to engage in CE activities and firms that do not commit to CE activities because certain problems – deterring barriers – discourage them from doing so.

3. Data and empirical strategy

3.1. Database and descriptive statistics

The empirical analysis reported here draws on data taken from the Flash Eurobarometer Survey 441 on "European SMEs and the Circular Economy". The survey contains information obtained from interviews, conducted between 18 and 27 April 2016, with 10,618 managers of SMEs from the 28 Member States of the European Union. The survey is specifically concerned with micro (1–9 employees), small (10–49 employees) and medium-sized (50–249 employees) firms in the manufacturing, retail, services, and industrial sectors. This extensive survey explores SMEs' activities in relation to the CE and the barriers they face; however, its main disadvantage is that it is a cross-sectional dataset and so, inevitably, we are unable to determine simultaneity relations.

Our final database selection was subject to a process of filtering. The main filters were as follows: 1) in line with D'Este et al. (2012), we exclude from the analysis those firms that do not undertake CE activities or do not plan to do so and do not experience any barrier to CE – these firms with no aspirations or intentions to be resource-efficient should be distinguished from those firms that are undertaking CE activities; 2) we discard observations with missing values for the relevant variables. After filtering, our empirical analysis is based on an extensive sample of 10,098 European SMEs (Table 1). The sample is clearly dominated by firms belonging to the retail and services, and also by micro firms (1–9 employees).

[Table 1 around here]

Table 2 shows the main characteristics of the sample. Although it can be seen that there is a high level of involvement in activities contributing to the CE, the heterogeneity across countries is significant (Figure A.1). In particular, most European SMEs – 77% of the sample – undertake some CE activity to become more resource efficient, though on average the SMEs implement just 1.7 CE activities each. Regarding the frequency with which CE activities are undertaken, SMEs report implementing one activity almost every quarter (24%), followed by those implementing two activities (22%) almost every quarter. Only 3% of the sample reports being involved in all the CE activities. Although the development of multiple strategies clearly reduces the risks to sustainability, at the same time such practices require extra training for employees, new equipment, and time to assimilate and adapt the new strategies.

It is also worth mentioning that not all CE activities are adopted to the same degree. For example, the most commonly adopted practices within the EU28 are those aimed at minimizing waste by recycling or reusing waste or selling it to another company (59%) and improving energy efficiency (43%). In contrast, SMEs are less likely to implement actions to re-plan water usage (20%) and to make a predominant use of renewable energy (18%). The low percentage associated with renewable energy may be attributable to the fact that it is cheaper for SMEs to go to the electricity market than it is to invest in renewable energies to meet their consumption needs, along with the fact that the energy demand model in which the consumer is at the same time a producer is still in its very early stages.

As for the barriers, most SMEs consider regulation – identified as complex administrative or legal procedures and the cost of meeting regulations or standards – the main barrier to carrying out CE activities. In contrast, relatively few – just a fifth of all the enterprises – mention the lack of human resources.

[Table 2 around here]

3.2. Empirical strategy

To analyse the relationship between engagement in CE activities and the challenges faced by firms, we estimate a multivariate probit model. The model allows the simultaneous estimation of the five barriers to the CE considered in this analysis – human resources, expertise, finance, administrative procedures, and the cost of meeting regulations. Existing evidence about innovation barriers suggests that the perceived obstacles are most likely to be correlated (D'Este et al., 2012), which leads us to consider that the firms' unobserved characteristics may jointly influence the different types of barrier to CE activities. Unlike univariate probit models, the multivariate probit approach allows us to incorporate a certain correlation structure for the unobservable factors related to different barriers. In this sense, the model considers the correlations between errors instead of assuming them to be zero or constant (Cappellari and Jenkins 2010). The model has a similar structure to that of a seemingly unrelated regression (SUR) model, except that the dependent variables are binary indicators.

The main specification can be summarized as follow:

$$Barriers_{ij} = \alpha_i + \beta_i\, CE_{ij} + \delta_i\, \text{Controls}_{ij} + \varepsilon_i \qquad \text{(Eq. 1)}$$

The dependent variables refer to the perception of the obstacles to the CE as specified by the SMEs. As mentioned in the previous section, we specifically address two sets of barrier: the lack of resources and capabilities, on the one hand, and regulation and complex administrative requirements, on the other. Limited to the variables available to us in our dataset, we use the lack of human resources, lack of expertise and difficulties in accessing finance to capture the first set of barriers and complex administrative procedures, and the cost of meeting regulations or standards to capture the second. In total five dependent variables, one for each *Barrier*, are constructed as dichotomous variables. Each dependent variable takes the value 1 if the firm has faced any obstacle in moving towards the CE, and 0 otherwise.

As explanatory variables (*CE*), different proxies of CE activities are introduced. To test our hypothesis, first we include a dummy variable indicating whether or not a firm is undertaking any CE activities in order to be more resource efficient. Then, moving on to the empirical test of whether the breadth of CE activities influences the perception of barriers, we introduce the number of CE activities implemented by each firm. Finally, following the idea that a distinction needs to be drawn between different typologies of CE activities to assess the barriers, we include a vector of five different types of CE activity: re-planning of the way water is used to minimize usage and maximize re-usage, use of renewable energy, re-planning energy usage to minimize consumption, minimizing waste by recycling or reusing waste or selling it to other firms and redesigning products and services to minimize the use of materials or use recycled materials.

To minimize any estimation bias due to an omitted variable, to all the equations we have added a series of control variables limited by the variables available in our dataset. To take into account relevant observable firm-level characteristics, we include the following controls: firm size, age (young), the role of technological capabilities (R&D), the financial situation of the firm (high turnover), whether the firm sells products or services directly to consumers (B2C) and the importance of financial support in implementing CE activities (little information CE). Finally, we introduce sector dummies (manufacturing, retail, services, and industry) and country dummies (Annex 1).

4. Results and discussion

The results of the estimations are presented in Tables 3, 4 and 5. For all specifications, we report the correlation parameters. The results show the convenience of using multivariate probit models so that the possible existence of complementarities between barriers is taken into account. In all the estimations, the coefficients of these correlation parameters are positive and significant. This suggests that the five barriers related to the lack of resources and capabilities and the presence of regulations are related and that individual estimations would be inconsistent. The correlation parameter of administrative procedures and the cost of meeting regulations is the highest, which shows the high degree of complementarity between these two barriers.

The estimations of the relationship between being engaged in any CE activity and the perception of barriers regarding the lack of resources and capabilities and the regulation and cost of administrative procedures show that it is important to distinguish between deterring and revealed obstacles and that the relationship differs across the five barriers considered (Table 3). In line with earlier contributions to the literature, our results show that the regulatory obstacles – i.e. the cost of complying with regulations and the existence of complex administrative and legal procedures – are the main barriers. Rizos et al. (2015), for example, identified the lack of effective regulation and administrative burdens as being perceived by firms as the main barriers to the development of the CE. In addition, and consistent with previous evidence (e.g. del Río et al., 2016), the lack of human resources is also perceived as an obstacle by firms engaged in CE, since greater levels of change require more trained and specialized employees.

[Table 3 around here]

The results of the estimations taking the number of CE activities (breadth) carried out into account (Table 4) confirm the previous conclusions and provide new insights into the relationship between being engaged in CE activities and the role of barriers.

First, these results confirm the importance of the existing regulatory framework obstacles. Firms consider administrative procedures and the cost of meeting regulations and standards barriers to be highly important. Nevertheless, while all firms perceive the administrative procedures as an obstacle regardless of the number of CE activities that they are engaged in, the cost of meeting regulations only emerges as a significant obstacle when firms begin to become more evidently involved in the CE activities and are implementing more than one activity.

Second, the estimations for the resource and capability obstacles confirm that the lack of human resources hampers CE activities, while being engaged in more than one CE activity increases perceptions of financial obstacles. This result is in line with Aranda-Usón et al. (2019) who examine the characteristics of the financial resources used for engaging in CE activities and find that inadequate financial schemes result in the slower adoption of CE activities, particularly in the case of SMEs.

Specifically, the firms that engage in three or more CE activities consider the difficulties in accessing finance as constituting a significant obstacle. This result suggests that while firms are able to finance one specific CE activity, when they become involved in several, they are very likely to have to resort to external finance and to encounter difficulties in obtaining the necessary funds to perform these activities. Finally, the results from these estimations show that a lack of expertise in implementing CE activities deters firms from engaging in them. Nevertheless, it

seems there is a learning effect and when they become engaged in more than one CE activity this obstacle loses importance.

[Table 4 around here]

The relationship between being engaged in a specific CE activity and the perception of barriers differs substantially across CE activities. When we shift from the engagement in generic to specific kinds of CE activity, we observe that the five CE activities considered (re-plan water usage, use of renewable energy, re-plan energy usage, minimize waste and redesign products and services) have different effects on the costs of the firms and are associated with different degrees of complexity. This indicates that their implementation may require specific resources and/or capabilities and firms may have to face different regulatory obstacles.

Our estimations (Table 5) highlight again the importance of regulations and administrative and legal procedures in the transition to a CE. These obstacles are significant for the five CE activities included in the estimations. However, the lack of appropriate human resources, which, as pointed out above, appears as a relevant obstacle in general for performing CE activities, is only perceived as a significant barrier by firms that are undertaking CE activities to minimize usage of water and maximize its re-usage and to redesign products and services to minimize the use of materials or using recycled materials. A similar result is obtained for the obstacle to access finance, which is also considered important by the firms that are engaged in these two CE activities related to the use of water and the redesigning of products and services.

The estimations also show that the five CE activities are notably different and undertaking one activity may present more obstacles than another. This is the case with the redesigning of products – the activity that requires the most substantial innovations and disruptive practices – which is the only CE activity for which we find positive and significant coefficients for all five barriers.

Finally, our results regarding the control variables provide information about the characteristics of the firms that affect their perception of the barriers to their undertaking CE activities. The main results are as follows: First, firm size is related to the perception of barriers but only in the case of financial obstacles, being non-significant for the rest of the barriers. This result is similar to those obtained in analyses of the characteristics of firms that account for R&D and innovation investments, which show that a lack of finance hampers innovation activities. Second, the age of the firm is also related with the perception of financial obstacles. Young firms face more difficulties in accessing the funds required to undertake CE activities, a result also found for innovation activities. Young firms also perceive the lack of human resources as a barrier to their performing CE activities. Third, firms investing in R&D consider all barriers – except the cost of meeting regulations – of high importance. This result suggests, as pointed out above, that the barriers to undertaking CE activities are more of a revealed than a deterring nature.

We also analysed whether there are differences between the perceptions of firms that sell goods or services directly to consumers (B2C) and those of firms that sell to other firms or organisations. Our results show that the former are especially concerned by the barriers to undertaking CE activities. Finally, we examined if a lack of information, particularly about accessing finance, has an influence on the perception of barriers to undertaking CE activities. The results show that there is a positive relationship for the five obstacles considered and the firms that perceive there to be 'little or no information readily available' have a negative perception of the obstacles.

[Table 5 around here]

5. Conclusions

Over recent decades, the need to advance towards a more sustainable future by adopting new circular business models has received increasing attention from academics, policy makers and managers alike. In the European context, the European Commission, in its recent 2050 strategic vision proposal, identifies the CE as a priority in achieving a prosperous, modern, competitive and climate neutral economy. The potential benefits of the CE are clear stated in the literature and range from providing opportunities for reducing negative environmental impacts and cost savings to increasing possibilities for business growth, development and innovation. Yet, achieving those benefits is not straightforward since activities aimed at boosting the CE face several barriers that inhibit a firm's implementation of them.

This paper, in an effort to contribute to the literature on firms' behaviour in relation to environmental practices, has focused specifically on the barriers to CE activities constituted by the lack of resources and capabilities and the existing regulatory framework. In seeking to address some of the limitations of previous studies, which have employed case study methodologies and that are overly reliant on the Chinese context, here we use a broad dataset encompassing a large sample of SMEs in 28 European countries and employ a rigorous econometric methodology which, compared to case studies, allows us to draw general conclusions as to the strength of relationships between different variables. Hence, this study reports novel results both in terms of both the geographical and methodological dimensions of the literature on CE.

Applying a multivariate probit approach, we obtain empirical results that suggest that European SMEs innovating in the area of the CE face various challenges and experience several types of barrier. SMEs engaging in CE activities are more likely to identify regulatory obstacles than those that do not engage in such activities. The importance of the regulation obstacle – complex administrative procedures and costs of meeting regulations or standards – is further confirmed when the number and type of CE actions are taken into account. Additionally, we find that a lack of human resources – that is, a lack of technical skills – represents a major challenge when seeking to identify and implement new circular business models.

We also highlight the fact that not all barriers play the same role or have the same impact and, consequently, it is important to distinguish between revealed barriers – i.e. those that reflect the degree of difficulty of implementing CE activities and the learning experience associated with such processes – and deterring barriers – i.e. those that are considered insurmountable. In this respect, barriers such as regulatory obstacles and the lack of human resources can be considered revealed barriers, whereas the lack of expertise in new technologies and the capability to change the mind-set to face the long-term are deterring barriers.

Our empirical results also point to the need to differentiate between different CE activities, since the perception of barriers differs substantially across these activities. Firms undertaking a disruptive innovation redesigning goods and services to minimize the use of materials are more likely to perceive all five barriers as important. However, firms implementing such activities such as minimizing waste, re-planning energy usage to minimize consumption and using renewable energy only perceive those obstacles related to administrative procedures and regulations.

Our results have a number of policy implications as to how the main obstacles to implementing CE activities among European SMEs might be overcome. First, policy makers need to better understand the complex challenges faced by SMEs, identifying the factors that hamper or slow down CE activities in order to design appropriate instruments to tackle this situation. The

transition towards the CE implies a complex set of administrative and legal procedures stemming from environmental legislation that frequently requires SMEs to dedicate excessive financial and time resources to addressing them. Indeed, SMEs have made frequent calls for a less strict and simpler legislative framework as a pre-requisite for their moving towards the CE.

The preceding analysis has provided useful insights into the relationship between engagement in CE activities and the challenges faced by SMEs. However, we should mention a number of limitations that future research might address. First, because we have only employed cross-sectional data, some of the variables in the model could be simultaneously determined, which hinders identification of causal relationships. This approach could usefully be extended by introducing temporal dynamics into the analysis as and when data become available. Panel data models are especially recommendable since they allow non-observable heterogeneity to be controlled for and long-term relationships between variables to be examined. Second, we have examined a set of barriers that we consider relevant in terms of their relationship with CE activities; however, to some degree they have been dictated by data availability. Additional research, though, should seek to extend the analysis to include such obstacles as technological and social barriers. Finally, although CE policy programs have been introduced by the EU, progress is highly dependent on the national policy frameworks in place. At times, specific instruments and priorities fall outside the legislative competence of the EU, leading to countries following quite distinct paths. Our research here has focused on what it is that hampers CE activities in the European Union, while a disaggregation of EU into its 28 Member States would help provide more specific empirical evidence and might lead to a broader understanding of the barriers to the CE. This, in turn, might improve the adaptation of policies to the intrinsic geo-characteristics of the region or country in question.

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Table 1. Distribution of the sample by cluster, sector and firm size

EU15 Members			**New EU Members**		
Country	**Firms**	**Percent**	**Country**	**Firms**	**Percent**
FR—France	392	3.88	CY—Cyprus	192	1.90
BE—Belgium	387	3.83	CZ—Czech Republic	364	3.60
NL—The Netherlands	382	3.78	EE—Estonia	369	3.65
DE—Germany	373	3.69	HU—Hungary	383	3.79
IT—Italy	389	3.85	LV—Latvia	382	3.78
LU—Luxembourg	192	1.90	LT—Lithuania	390	3.86
DK—Denmark	367	3.63	MT—Malta	193	1.91
IE—Ireland	379	3.75	PL—Poland	377	3.73
GB—United Kingdom	361	3.57	SK—Slovakia	380	3.76
GR—Greece	386	3.82	SI—Slovenia	386	3.82
ES—Spain	386	3.82	BG—Bulgaria	369	3.65
PT—Portugal	392	3.88	RO—Romania	384	3.80
FI—Finland	388	3.84	HR—Croatia	394	3.90
SE—Sweden	367	3.63			
AT—Austria	394	3.90			
Total EU15	5535	54.82	Total new members	4563	45.18
Firms by sector					
Manufacturing (NACE C)	662	11.96	Manufacturing	739	16.20
Retail (NACE G)	1833	33.12	Retail	1633	35.79
Services (NACE H/I/J/K/L/M/N)	2329	42.08	Services	1548	33.93
Industry (NACE B/D/E/F) (1)	711	12.85	Industry	643	14.09
Firms by nº of employees					
1 to 9	3494	63.13	1 to 9	2807	61.52
10 to 49	1267	22.89	10 to 49	1113	85.91
50 to 249	774	13.98	50 to 249	643	14.09

Source: Flash Eurobarometer Survey 441, European Commission.

(1) Mining, Energy, Water and Construction

Table 2. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Dependent variables (Barriers)					
Lack of resources and capabilities					
Human resources	10,098	0.2066	0.4049	0	1
Expertise	10,098	0.2244	0.4172	0	1
Finance	10,098	0.2367	0.4251	0	1
Regulations and cost of administrative requirements					
Administrative procedures	10,098	0.2877	0.4527	0	1
Cost meeting regulations	10,098	0.2624	0.4399	0	1
Independent variables (CE)					
Circular Economy	10,098	0.7693	0.4212	0	1
Types of CE					
Re-plan water usage	10,098	0.1972	0.3979	0	1
Renewable energy	10,098	0.1824	0.3862	0	1
Energy efficiency	10,098	0.4259	0.4945	0	1
Minimize waste	10,098	0.5947	0.4909	0	1
Redesign products	10,098	0.3603	0.4801	0	1
Breadth (number of CE activities)					
CE 1	10,098	0.2443	0.4296	0	1
CE 2	10,098	0.2227	0.4160	0	1
CE 3	10,098	0.1722	0.3775	0	1
CE 4	10,098	0.0962	0.2949	0	1
CE 5	10,098	0.0338	0.1808	0	1
Control variables					
Size	10,098	20.997	38.687	0	250
Young	10,098	0.1638	0.3701	0	1
R&D (%)	10,098	0.0293	0.1058	0	1
High turnover	10,098	0.5007	0.5000	0	1
B2C	10,098	0.4003	0.4899	0	1
Little information CE	10,098	0.2492	0.436	0	1
Manufacturing	10,098	0.1387	0.3456	0	1
Retail	10,098	0.3432	0.4748	0	1
Services	10,098	0.3839	0.4863	0	1
Industry	10,098	0.1340	0.3407	0	1

Source: Flash Eurobarometer Survey 441, European Commission.

Table 3. Baseline: Barriers hampering CE. Multivariate probit results

	Human resources	Expertise	Finance	Administrative Procedures	Cost meeting regulations
CE	0.190*	-0.0831	0.0391	0.428***	0.327***
	(0.0863)	(0.0615)	(0.0541)	(0.0598)	(0.0689)
Size	0.0142	0.00394	-0.0431**	0.0231	0.00980
	(0.0121)	(0.00942)	(0.0161)	(0.0149)	(0.00951)
Young	0.121**	0.0400	0.139***	-0.0101	0.00928
	(0.0374)	(0.0436)	(0.0307)	(0.0404)	(0.0399)
R&D	0.541***	0.350*	0.561***	0.592***	0.186
	(0.130)	(0.158)	(0.138)	(0.110)	(0.138)
High turnover	0.125***	0.161***	0.0554	0.121***	0.103**
	(0.0378)	(0.0431)	(0.0365)	(0.0366)	(0.0320)
B2C	0.270***	0.191**	0.426***	0.242***	0.207**
	(0.0570)	(0.0684)	(0.0570)	(0.0666)	(0.0664)
B2C*CE	-0.220**	-0.169*	-0.334***	-0.212**	-0.154
	(0.0776)	(0.0777)	(0.0668)	(0.0773)	(0.0833)
Little inform. CE	0.271***	0.285***	0.526***	0.421***	0.359***
	(0.0260)	(0.0294)	(0.0449)	(0.0384)	(0.0391)
Sector: ref. Industry					
Manufacturing	-0.0209	-0.0810	-0.118*	-0.153**	-0.109
	(0.0571)	(0.0526)	(0.0529)	(0.0570)	(0.0599)
Retail	-0.214***	-0.143**	-0.301***	-0.236***	-0.276***
	(0.0522)	(0.0497)	(0.0427)	(0.0568)	(0.0569)
Services	-0.150***	-0.157***	-0.245***	-0.253***	-0.283***
	(0.0428)	(0.0426)	(0.0468)	(0.0521)	(0.0616)
Constant	-0.690***	-0.368***	-0.511***	-0.402***	-0.171*
	(0.0725)	(0.0620)	(0.0704)	(0.0682)	(0.0739)
Country dummies	Yes				
atrho21	0.542***				
	(0.0231)				
atrho31	0.410***				
	(0.0198)				
atrho41	0.435***				
	(0.0234)				
atrho32	0.510***				
	(0.0187)				
atrho51	0.450***				
	(0.0237)				
atrho32	0.475***				
	(0.0185)				
atrho42	0.495***				
	(0.0210)				
atrho52	0.428***				
	(0.0221)				
atrho43	0.710***				
	(0.0249)				
atrho53	0.496***				
	(0.0254)				
atrho 54	0.526***				
	(0.0243)				
Observations	10098				
Likelihood ratio test rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52= rho43 = rho53 = rho54 = 0					5295.87 ***
Log pseudolikelihood	-23459.2				

Clustered standard errors by country in parentheses (28 clusters). *, **, and *** correspond to significance levels of 1%, 5%, and 10%, respectively.

Table 4. Breadth of CE activities and barriers. Multivariate probit results

	Human resources	Expertise	Finance	Administrative Procedures	Cost meeting regulations
Number of CE activities					
CE (1)	0.0763	-0.177**	-0.118	0.222***	0.136
	(0.0924)	(0.0571)	(0.0608)	(0.0572)	(0.0761)
CE (2)	0.240*	-0.0237	0.103	0.441***	0.357***
	(0.0942)	(0.0821)	(0.0562)	(0.0783)	(0.0783)
CE (3)	0.253**	0.00647	0.142*	0.586***	0.481***
	(0.0847)	(0.0632)	(0.0660)	(0.0666)	(0.0808)
CE (4)	0.304**	-0.0799	0.151*	0.670***	0.513***
	(0.108)	(0.0815)	(0.0713)	(0.0863)	(0.0738)
CE (5)	0.263**	-0.123	0.200*	0.779***	0.548***
	(0.0949)	(0.0754)	(0.0999)	(0.0996)	(0.0959)
Size	0.0100	0.00161	-0.0494**	0.0116	0.000582
	(0.0122)	(0.00967)	(0.0164)	(0.0145)	(0.00940)
Young	0.128***	0.0431	0.146***	0.00113	0.0196
	(0.0372)	(0.0440)	(0.0295)	(0.0401)	(0.0395)
R&D	0.512***	0.335*	0.519***	0.520***	0.124
	(0.130)	(0.156)	(0.138)	(0.108)	(0.138)
High turnover	0.122**	0.159***	0.0530	0.120***	0.101**
	(0.0378)	(0.0429)	(0.0366)	(0.0365)	(0.0312)
B2C	0.268***	0.191**	0.424***	0.232***	0.200**
	(0.0579)	(0.0690)	(0.0566)	(0.0681)	(0.0669)
B2C*CE	-0.223**	-0.171*	-0.337***	-0.214**	-0.156
	(0.0784)	(0.0784)	(0.0667)	(0.0787)	(0.0845)
Little information CE	0.260***	0.278***	0.514***	0.400***	0.340***
	(0.0272)	(0.0298)	(0.0447)	(0.0367)	(0.0388)
Sector: ref. Industry					
Manufacturing	-0.0269	-0.0851	-0.123*	-0.158**	-0.115
	(0.0583)	(0.0525)	(0.0554)	(0.0588)	(0.0595)
Retail	-0.208***	-0.142**	-0.292***	-0.215***	-0.260***
	(0.0525)	(0.0499)	(0.0456)	(0.0575)	(0.0578)
Services	-0.145***	-0.153***	-0.238***	-0.239***	-0.272***
	(0.0440)	(0.0422)	(0.0484)	(0.0520)	(0.0616)
Constant	-0.689***	-0.368***	-0.514***	-0.403***	-0.169*
	(0.0737)	(0.0624)	(0.0707)	(0.0690)	(0.0768)
Country dummies	Yes				
atrho21	0.542***				
	(0.0225)				
atrho31	0.407***				
	(0.0198)				
atrho41	0.432***				
	(0.0237)				
atrho51	0.447***				
	(0.0231)				
atrho32	0.476***				
	(0.0180)				
atrho42	0.495***				
	(0.0205)				
atrho52	0.427***				
	(0.0221)				
atrho43	0.701***				
	(0.0249)				
atrho53	0.489***				
	(0.0253)				
atrho54	0.519***				
	(0.0247)				
Observations	10098				

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0	5206.15***
Log pseudolikelihood	-23362.0

Clustered standard errors by country in parentheses (28 clusters). *, **, and *** correspond to significance levels of 1%, 5%, and 10%, respectively.

Table 5. Types of CE and Barriers. Multivariate probit results

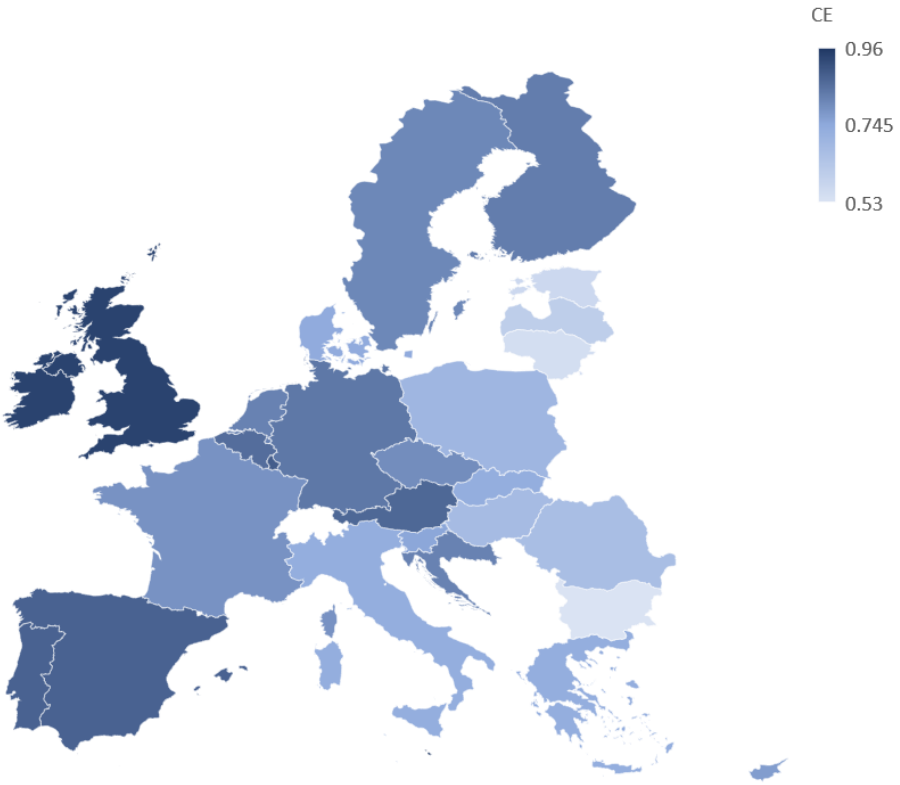
	Human resources	Expertise	Finance	Administrative Procedures	Cost meeting regulations
Water	0.119***	0.0322	0.147***	0.145***	0.193***
	(0.0328)	(0.0305)	(0.0407)	(0.0345)	(0.0363)
Renewable	-0.000606	0.000840	0.0470	0.197***	0.0955*
	(0.0406)	(0.0354)	(0.0516)	(0.0381)	(0.0431)
Energy eff.	0.0314	-0.0632	0.00788	0.110**	0.102**
	(0.0361)	(0.0332)	(0.0318)	(0.0411)	(0.0356)
Waste	-0.00548	-0.0492	-0.0312	0.137***	0.0783*
	(0.0431)	(0.0350)	(0.0405)	(0.0340)	(0.0328)
Redesign	0.180***	0.113***	0.144***	0.226***	0.168***
	(0.0330)	(0.0319)	(0.0301)	(0.0386)	(0.0378)
Size	0.0127	0.00317	-0.0470**	0.0130	0.00228
	(0.0119)	(0.00964)	(0.0167)	(0.0142)	(0.00944)
Young	0.121**	0.0378	0.141***	-0.00198	0.0160
	(0.0370)	(0.0436)	(0.0302)	(0.0405)	(0.0400)
R&D	0.500***	0.323*	0.503***	0.508***	0.112
	(0.135)	(0.159)	(0.137)	(0.106)	(0.142)
High turnover	0.128***	0.161***	0.0576	0.124***	0.106***
	(0.0377)	(0.0420)	(0.0362)	(0.0362)	(0.0314)
B2C	0.217***	0.242***	0.459***	0.162**	0.142*
	(0.0574)	(0.0643)	(0.0587)	(0.0582)	(0.0670)
B2C*CE	-0.156*	-0.234**	-0.381***	-0.126	-0.0848
	(0.0752)	(0.0715)	(0.0676)	(0.0698)	(0.0766)
Little information CE	0.263***	0.279***	0.515***	0.404***	0.344***
	(0.0271)	(0.0293)	(0.0453)	(0.0371)	(0.0390)
Sector: ref. Industry					
Manufacturing	-0.0198	-0.0847	-0.117*	-0.149*	-0.106
	(0.0568)	(0.0507)	(0.0539)	(0.0595)	(0.0616)
Retail	-0.198***	-0.138**	-0.284***	-0.204***	-0.250***
	(0.0521)	(0.0492)	(0.0429)	(0.0580)	(0.0591)
Services	-0.146***	-0.153***	-0.238***	-0.236***	-0.274***
	(0.0437)	(0.0431)	(0.0479)	(0.0527)	(0.0622)
Constant	-0.661***	-0.435***	-0.566***	-0.351***	-0.130*
	(0.0514)	(0.0545)	(0.0609)	(0.0591)	(0.0541)
Country dummies	Yes				
atrho21	0.538***				
	(0.0233)				
atrho31	0.407***				
	(0.0198)				
atrho41	0.430***				
	(0.0241)				
atrho51	0.445***				
	(0.0240)				
atrho32	0.474***				
	(0.0180)				
atrho42	0.495***				
	(0.0208)				
atrho52	0.428***				
	(0.0222)				
atrho43	0.702***				
	(0.0249)				
atrho53	0.488***				
	(0.0252)				
atrho54	0.517***				
	(0.0242)				

Observations	10098
Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0	5193.43***
Log pseudolikelihood	-23368.1

Table A.1 Variable Definitions

Variable definitions	
Dependent variables	
Barriers to CE activities	Human resources: dummy variable that takes the value 1 if the firm has faced an obstacle to CE activities related to lack of human resources; 0 if not Expertise: dummy variable that takes the value 1 if the firm has faced an obstacle to CE activities related to lack of expertise; 0 if not Finance: dummy variable that takes the value 1 if the firm has faced an obstacle to CE activities related to difficulties in accessing finance (external or internal financial support); 0 if not Administrative procedures: dummy variable that takes the value 1 if the firm has faced an obstacle to CE activities related to complex administrative or legal procedures; 0 if not Cost meeting regulations: dummy variable that takes the value 1 if the firm has faced an obstacle to CE activities related to the cost of meeting regulations or standards; 0 if not
Independent variables	
CE activities	Circular economy: dummy variable that takes the value 1 if the firm states it undertook any of the following activities in the last 3 years; 0 if not ➢ Water: re-plan the way water is used to minimize usage and maximize re-usage ➢ Renewable energy: use of renewable energy ➢ Energy efficiency: re-plan energy usage to minimize consumption ➢ Waste: minimize waste by recycling or reusing waste or selling it to another company ➢ Redesign: redesign products and services to minimize the use of materials or use recycled materials Breadth: number of circular economy activities undertaken by the firm (range from 0 to 5)
Control variables	
Size	Log of the total number of a firm's employees
Young	Dummy variable that takes a value equal to 1 if a firm is less than 6 years old; 0 if not
R&D	Percentage of a firm's turnover invested in R&D activities
High turnover	Dummy variable that takes a value 1 if a firm's total turnover is higher than 100,000 euros; 0 if not
B2C	Dummy variable that takes a value 1 if a firm sells products or services directly to consumers; 0 if not
Little information CE	Dummy variable that takes a value 1 if a firm states there is little or no information available to help firms access finance for activities related to CE; 0 if not
Sector	Sector-specific dummy variables. This indicates the main activity of the company: manufacturing, retail, services and industry

Figure A. 1. Map of CE activities across European Countries



Source: Based on Flash Eurobarometer Survey 441, European Commission