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Measurement of the circular economy in businesses: impact and implications for regional policies

Alfonso Aranda-Usón
Universidad de Zaragoza – Departamento de Contabilidad y Finanzas – Facultad de Economía y Empresa alaranda@unizar.es

José M. Moneva
Universidad de Zaragoza – Departamento de Contabilidad y Finanzas – Facultad de Economía y Empresa jmmoneva@unizar.es

Pilar Portillo-Tarragona
Universidad de Zaragoza – Departamento de Contabilidad y Finanzas – Facultad de Economía y Empresa portillo@unizar.es

Fernando Llena-Macarulla
Universidad de Zaragoza – Departamento de Contabilidad y Finanzas – Facultad de Economía y Empresa fllena@unizar.es

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Abstract

Currently, numerous governments and international organisations are promoting the implementation of the circular economy – both within the EU and in other regions – as an alternative to lineal models, and in search of a compromise between competitiveness and the sustainable exploitation of resources.

The implementation of a circular business model is closely tied to the territory within which firms operate. As a result, firms are highly sensitive to the existence of favourable conditions at the regional level, which can greatly accelerate the transition towards circular models and regions play a relevant role in the adoption of the circular economy principles by the private sector.

Similarly, the adoption of models based on circular economy principles at the micro level has an effect on macro indicators at the regional level, especially concerning the flow of raw materials and other resources, and this contributes to ensuring that quality standards and resource availability are maintained throughout the value chain. The effects of the adoption of these models on a territory can be measured in terms of volume of transactions, generation of jobs and consumption of raw materials. In this context, this study aims to contribute to the measurement of the activities related to the circular economy that have been implemented at regional level by business. This allows us to improve the knowledge of the socioeconomic impact of the circular economy, and offer an empirical approach for the development of specific regional policies to improve the circular economy in businesses.

1. Introduction

Today, the concept of circular economy (CE) is used by policy makers, academics and practitioners to refer to a sustainable economic model that does not compromise economic growth (Pratt, Lenaghan, & Mitchard, 2016). The CE paradigm is characterised by efficient flows of resources, waste, energy, materials, labour and information, which ensure that natural and social capital is constantly replenished. The aim of a CE is to create circular (closed) loops in which raw materials and other resources are used repeatedly in different phases (Yuan et al., 2006), allowing for the added value of products to be maintained for as long as possible while contributing to waste reduction.

There is wide agreement that the CE can offer an attractive and viable alternative to lineal 'take, use and discard' models, generating value both, for private firms and for society in general. In this regard, the competitiveness of private firms depends on reaching a compromise between productivity and the sustainable and efficient use of resources, prompting private firms to achieve 'more with less' in their transactions (Ellen MacArthur Foundation, 2015b). As such, these models are being promoted by numerous governments and international organisations in the EU and in other.

CE is becoming an increasing object of attention among academics of the social sciences field. A growing number of quantitative studies are contributing to examination and development of the model (Ghisellini, Cialani, & Ulgiati, 2016; Kirchherr, Reike, & Hekkert, 2017; Korhonen, Honkasalo, & Seppälä, 2018; Merli, Preziosi, & Acampora, 2018; Pomponi & Moncaster, 2017; Urbinati, Chiaroni, & Chiesa, 2017). Private firms are also showing a burgeoning interest in CE (Lewandowski, 2016), although the adoption of this model by private firms remains poorly understood (Stewart & Niero, 2018). To date, the literature has mainly been focused on the factors that affect the commitment of private firms to the CE, existing barriers and incentives to the adoption of the model, and the impact of CE on the organisation of firms. The measurement of CE on firm performance is still under discussion, and, to the best of our knowledge, no empirical results concerning the dissemination of the model within a given territorial framework or its impact, exists. For this reason, the present study focuses on the analysis of territorial promotion of the CE, with the ultimate aim of evaluating its impact at the micro level and its implications at the regional level.

As such, this article considers the adoption of the CE in the private sector and its impact at the regional level within the same analytical framework, while also considers the different analytical frameworks in which the issue is currently being examined in the literature (Franco, 2017). In order to do this, after investigating the general background, we shall analyse the adoption of the CE in businesses located on a Spanish region. This approach will result in theoretical and methodological considerations as to how to measure the adoption of the CE in the private sector within a given territorial framework. This private-sector focused perspective will give a specific context in which to introduce the concept of CE. Finally, we summarise the main results to state conclusions and to reflect on future perspectives and challenges in the mid- and long-term.

2. Background

In general, the principles of the CE were developed within the theoretical framework of ecological economics. In this framework, the economy is considered a subsystem of the ecological system, the environmental and material resources of which are limited. Liu et al. (2009), following Pearce and Turner (1990), consider that the unbalanced relationship between ecosystem and economy began with the industrial revolution, going on to argue that the CE is a potential solution as it contributes to more balanced and sustainable material flows (Su et al., 2013).

As noted in the introduction, a CE offers a sustainable growth-based model which advocates for the effective integration of environmental and economic factors, with the aim of achieving the production goods and services while reducing the consumption and waste of raw materials, water and other resources. With the adoption of the model by private firms (Li et al., 2010), the CE can contribute to a more efficient use of raw materials and resources (Liu et al., 2009), and to cleaner production and greater efficiency by increasing circularity and a fuller use of resources (Jun & Xiang 2011; Van Berkel 2010).

The effective implementation of a CE results in more innovative, resilient and efficient production models. Improved material flows limit firms' exposure to price volatility, while innovation generates jobs and increases economic resilience; conversely, territorial degradation, loss of fertile soils and biodiversity, is very costly in economic terms (Ellen MacArthur Foundation, 2015a).

The European Commission argues that in a CE the added value of products can be maintained for longer while reducing waste (European Commission, 2014), with repeated reuse of products that have otherwise reached the end of their life-cycle thus generating more value. The advantages of this productive model are leading numerous governments and organisations to promote its adoption at the territorial level. The development of the circular model is closely dependent on a regional system's ability to sustain innovation and enhance its industrial profile (Coats and Benton, 2015; Walendowski et al., 2014). As such, there is little doubt that regional and local public policies can contribute to promote development models such as that presented by the CE.

In the European Union (EU), the communication 'Towards a circular economy: A zero waste programme for Europe' and its annex (European Commission, 2014) laid foundations for the promotion of CE in the EU's member states. These recommendations were further developed the following year in the communication 'Closing the loop: An EU action plan for the circular economy' (European Commision, 2015). The key measures recommended in these communications chiefly addressed production (product and process design), consumption (consumers and collaborative economies), waste management (establishing a hierarchy of waste, among other considerations) and the transformation of waste into resources. Priority action areas included management of plastics, food waste, critical raw materials, construction sector waste, biomass and bio-products, as well as innovation, investment and other horizontal measures. Among the EU's ongoing initiatives are those concerning plastics (European Commission, 2018a), energy extraction from waste (European Commission, 2017) and critical raw materials (European Commission, 2018b), in addition to those concerning renewable energy, eco-design and energy efficiency.

The priorities set forth by the EU incorporate the measures that most developed countries promoting CE consider to be most relevant (Mathews & Tan, 2016). China led the way in enacting the Circular Economy Act (Republic of China, 2008) (Republic of China, 2008), which was the first time that the promotion of CE was elevated to the status of law. This Act is based on the '3R principle' (reducing, reusing and recycling), and considers re-manufacturing to be an effective way of promoting CE (Zhang et al., 2011). Similarly, other countries such as Japan and the United Kingdom (Despeisse et al., 2015) are using the principles of CE to promote recycling and product reuse. Other EU member states have adopted several measures conducive to the implementation of CE principles, including subsidies for eco-design, the public acquisition of products and services that meet CE-based environmental standards, tax breaks for green technologies, and the promotion of recycled or sustainable materials, etc. (Portillo-Tarragona, Scarpellini, Llena, & Aranda-Usón, 2017).

Promoting a circular economy has been identified as China's basic national policy since 2005 (Zhijun & Nailing, 2007). Nowadays, the development of China's CE is higher in such regions where governmental officials have better awareness and strong drivers to make changes (Xue et al., 2010). However, some challenges have been pointed out in order to improve the introduction of the CE in China, such as a lack of reliable information, shortage of advanced technology, poor enforceability of legislation, weak economic incentives, poor leadership and management, and lack of public awareness (Su et al., 2013).

At present, in Spain the promotion of CE is still under development, and a few public policies have focused on activities at the end of the economic cycle, such as waste management, for which a mid-term national plan is currently being implemented (Fundación COTEC para la Innovación, 2017). Regional and local initiatives that aim to promote the establishment of closed material loops within the framework of the National Strategy for the Promotion of Circular Economy for 2030 are also worth mentioning (Gobierno de España, 2018)[1]. However, although governments, private firms and wider society increasingly recognise the advantages of a CE, numerous barriers to its effective implementation still exist. The transition towards a CE needs to be encouraged both from the bottom up, as a result of changing social preferences, and from the top down, by government (EOI, 2016), so that all stakeholders – private firms, government and society – become fully involved.

Firms are highly sensitive to the existence of favourable conditions at the regional level, which can greatly accelerate the transition towards circular models (Yi & Liu, 2015). Regulation and public support increase the adoption of sustainable manufacturing practices such as the CE (Moktadir, Rahman, Rahman, Ali, & Paul, 2018). The CE is influenced by geographical proximity since the approach of activities at local and regional level helps to reduce the costs derived from broader circuits with a greater number of transactions (Stahel, 2013). Thus, local and regional authorities can also play an important role in both, the launch of and transition to a CE (Yi & Liu, 2015) because the implementation of a circular business model is closely tied to the territory within which firms operate.

As with all transitional processes, the CE-related benefits will not be evenly distributed: it is likely that some industrial sectors, firms, regions and social groups will be relatively worse off, while others benefit. The ability to reap these benefits will largely depend on the ability and the agility with which the relevant skills are acquired by both firms and public institutions, factors that are largely dependent on the regional setting (EEA, 2016).

[1] While the current paper was being prepared, the strategy was pending official endorsement.

The predicted environmental, economic and social advantages of the CE are summarised by the European Environment Agency (EEA, 2016).The main advantages have to do with resource-use efficiency (European Union, 2013) and the bridging of the current gap between economic growth resulting from the use of these resources and levels of social and environmental wellbeing. It is argued that a CE must go beyond the EUs current waste-reduction policies because keeping materials in the economic loop for longer will help to increase the resilience of ecosystems and avoid the environmental impact of resource extraction, which often takes place outside Europe. It is also argued that this could lead to a reduction in greenhouse gas emissions in the EU of 48% by 2030 and 83% by 2050, compared to 2012 levels, while cutting down €500 million in externality costs by 2030 (Ellen MacArthur Foundation, 2015b).

The economic advantages of adopting a CE relate to the substitution of circular models for linear models. The current linear model reduces economic opportunities, instead stunting the competitiveness of different economic sectors within the EU, which must compete for the same resources; this could be prevented by adopting innovative approaches and new circular business models. In economic terms, the CE can lead to a significant reduction of supply costs. In some sectors this reduction could range from 12% to as much as 23% (Ellen MacArthur Foundation, 2013).

The main social advantages of the adoption of the CE model are the generation of jobs and the promotion of more sustainable habits. New employment opportunities are largely related to recycling and the reuse of waste, sectors that generate direct employment (European Commision, 2015). It is expected that investment in new sectors will lead to further job creation, as the CE generates new employment opportunities both in the EU and Asia (Yuan, Bi, Moriguichi, & Zengwei Yuan, Jun Bi, 2006). Studies have analysed the impact of the CE on the labour market; it is predicted that the waste sector (preparation and classification of waste for reuse and recycling) will generate a large number of jobs, and that most CE-related employment opportunities will demand medium- or high-skilled workers (Morgan & Mitchell, 2015).

There is wide agreement that the adoption of a CE could result in job creation in some sectors and in job losses in others. For instance, in Spain, it is expected that the increase in the number of electric cars will lead to increased employment in the renewable electricity sector and to a likely decrease in employment in the mining and conventional electricity sectors; however, depending on the structure of economic sectors, the net employment balance can be positive (Wijkman, Skånberg, & Berglund, 2016).

3.1 The CE in the private sector

Firms play a crucial role in the development of the CE, promoting the efficiency of the economic system and allowing for resources to be used to the full in the productive cycle (Jun & Xiang, 2011). Initiatives and processes that lead to reduced energy and resource consumption by turning the waste from an industrial process into usable resources for another process must be analysed at this micro level (Mathews & Tan, 2011).

In order to analyse and select the measures to promote the CE in companies located in a territory, the results obtained by the European Commission in the public consultation on the CE in the EU in 2015 can be used[2]. Measures that are considered of special interest in this phase of implementation of the CE at the regional level are the promotion of initiatives led by industries (for example "self-regulation"), the development of voluntary standards and the promotion of eco-innovation and eco-design. Main measures that can increase the introduction of the CE in companies at a regional level are summarized in Table 1 that is based on the proposal of Su et al. (2013) in which the CE practices are organized into four groups.

Table 1. Selection of the CE-related potential policy measures for firms at regional level (with references).

CE Practices at micro level	*Potential Regional Policy Measures for firms*	*Regional/Local CE*

[2] Please see: http://makeresourcescount.eu/wp-content/uploads/2014/11/Response-to-Circular-Economy-Consultation.pdf (assessed on December 2018)

Production area	• Eco-design • Investments and impacts on the manufacturing costs • Introduction of the CE in the value chain • Improvement of the resource efficiency in processes • Neutral technology promotion of technology and digital solutions	(Cao & Zhang, 2011; Geng, Tsuyoshi, & Chen, 2010; Jiang, 2011; Pratt et al., 2016)
Consumption area and products	• Prolong life through maintenance, repair and design for durability • Design for upgradability and adaptability. • Improve consumers' green awareness	(Liu & Bai, 2014; Lukman, Glavič, Carpenter, & Virtič, 2016)
Waste management area	• Improve chemical and waste regulation • Promotion of the public-private collaboration	(Cao & Zhang, 2011; Smol, Kulczycka, & Avdiushchenko, 2017)
Other supports	• Corporate reporting • Best practices and technology transfer • Quality of information and data of material flows along the value chain • Voluntary standards	(Baur, 2011; Geng, Zhu, Doberstein, & Fujita, 2009; Walendowski et al., 2014)

Despite existing limitations, various indicators allow us to follow material, energy and water flows in the different stages of implementation of the CE (Van Berkel, 2010). Each system (non-renewable resources, emissions, soil use, impact on human health, social impact) is attached to a specific set of indicators (Pakarinen, Mattila, Melanen, Nissinen, & Sokka, 2010). As such, the different measurement systems available all have strengths and weaknesses, and no single methodology to measure the CE has gained widespread support. Furthermore, data sources are limited, while it is also important to take into consideration complicating factors as territorial structure, socio-economic variables and the impact of governmental initiatives (Jacobsen, 2006).

Our aim is to measure the dissemination of the CE among the private firms operating in a specific region selected as a case study. In this regard, it is useful to distinguish between firms that operate in sectors directly linked to the CE – e.g. recycling and waste management – and firms that operate in sectors that use the technologies highlighted in CE-related protocols – namely the BREF (Best available techniques Reference) documents (EIPPCB-TWG, 2003; European Comission, 2009; European Commission, 2003; European IPPC Bureau, 2006), which are regarded as more 'sensitive' to the adoption of circular models. Table 2 summarises the main activities related to a circular model, based on the existing literature.

Table 2. Selection of the CE-related activities in the firms (with references).

Main activities	*Authors*
In thermal recycling of waste within the firm	(Dong-her et al., 2018; Liu & Bai, 2014; Ormazabal, Prieto-Sandoval, Puga-Leal, & Jaca, 2018; Stewart & Niero, 2018)
Renewable energy facilities in the firm	(European Commission, 2016)
Eco-design and modification of processes towards dematerialisation	(Liu & Bai, 2014; Miroshnychenko, Barontini, & Testa, 2017; Ormazabal et al., 2018; Stewart & Niero, 2018)
Recycling-friendly product design	(Liu & Bai, 2014; Miroshnychenko et al., 2017; Stewart & Niero, 2018)
Use of secondary raw materials in production	(Fundación COTEC para la Innovación, 2017; Stewart & Niero, 2018)
Design for reliability and durability and design for extending product life(durability)	(Franco, 2017; Stewart & Niero, 2018)
Design for upgradability and flexibility(multifunction)	(Franco, 2017; Stewart & Niero, 2018)
Energy valorisation of waste	(Huysman, De Schaepmeester, Ragaert, Dewulf, & De Meester, 2017; Singh & Ordóñez, 2016)

In this context, our research questions are as follows:

R1: What are the most widespread the CE-related activities among the more CE-sensitive economic sectors in a given territorial framework?

R.2. What is the effect of closing material loops in a given territory?

In the following sections, we shall try to answer these questions by analysing the implementation of a CE at the micro and territorial levels.

3. Case study

At the territorial level, the CE is an important strategic tool, as it contributes to preventing environmental degradation and also help preserve scarce resources by efficiently managing solid waste and creating a closed materials loop flow within the regional economic system (Geng & Doberstein, 2008).

We shall focus our study on the Spanish region of Aragón,[3] which in recent years has witnessed an increase in the number of local, small-scale initiatives aiming towards the implementation of some of the principles of a CE (Portillo-Tarragona et al., 2017)[4]. Despite an increase in the number of such initiatives, CE principles remain underdeveloped in the region, and a key government target is to facilitate a gradual expansion of the model (Portillo-Tarragona et al., 2017). To date, the CE principles have been adopted in the waste management sector, but this is only one of the components that are needed for the integral implementation of all CE principles, according to the recommendations set forth by the EU. As such, the following section is an attempt to measure the adoption of the CE by businesses in Aragón at the firm level.

3.1 Measurement of CE in firms

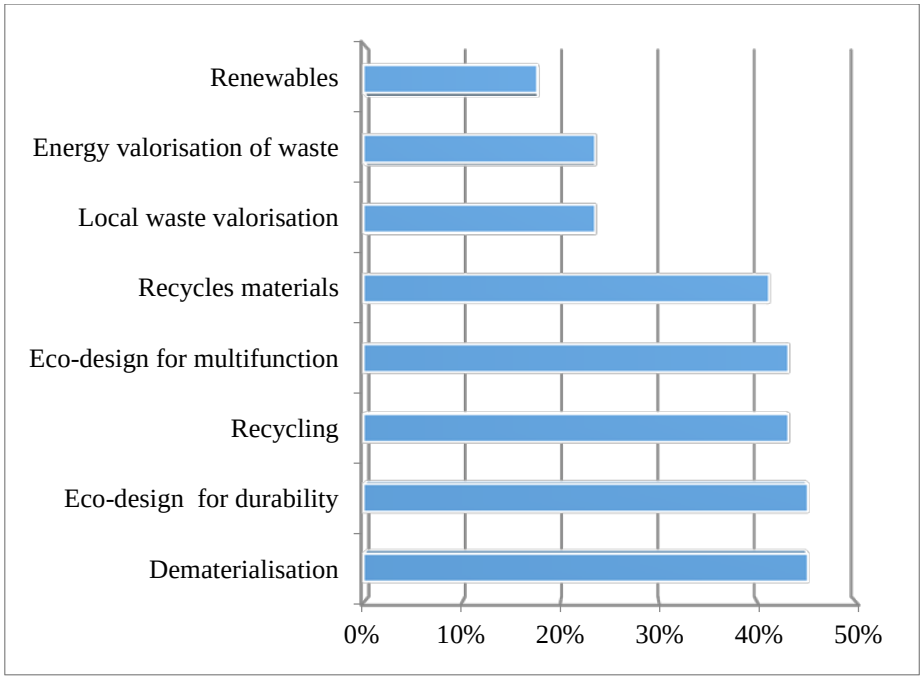
Since the recycling and waste management sectors can be directly related to a CE, it is necessary to measure the impact of the CE principles in other sectors in which different aspects of the model are being progressively implemented. The measurement of the CE-related activities in the firms operating in the most 'sensitive' sectors is carried out by means of a survey distributed within the framework of a collaborative research project involving firms interested in eco-innovation, eco-design and the CE in the Spanish north east. This study takes into consideration 51 firms in the region of Aragón.

Among the CE-related activities, we shall focus on those processes that take firms beyond environmental management and protection protocols, as described in Table 2. The most widespread among these are dematerialisation, eco-design (durability), recyclability, eco-design (multifunction) and use of secondary raw materials: all of these measures are implemented by approximately 40% of the firms within our sample. Other processes, however, have been adopted fewer of the firms, as illustrated in Figure 1. The five most widespread processes have been simultaneously adopted by approximately 20% of firms, while design-related activities (eco-design, dematerialisation and durability) are being implemented by approximately 30% of firms.

Figure 1. Percentage of firms that implement the CE-related activities

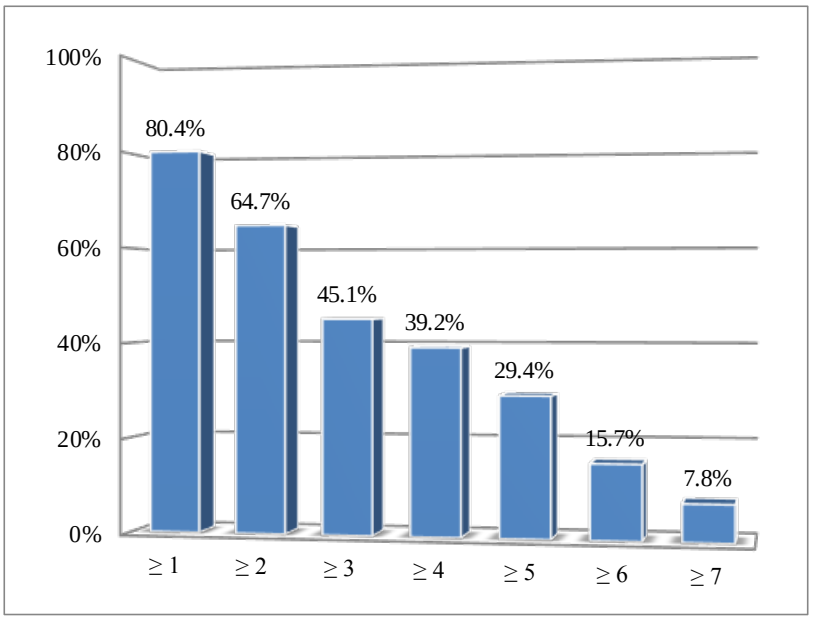
[3] While this paper was being written, a regional plan for the promotion of CE was in preparation.

[4] For more details see: https://ecodes.org/coalicion-de-empresas#.W-tS1pNKjIU



Most firms have adopted at least one the CE-related activity (80.4%), while over one-third have adopted at least four (39.2%). None of the firms in the sample carry out all the CE-related activities considered in this study, and only 7.8% (4 firms) carry out seven. The extent of the CE-related processes within the overall activity of the firms is illustrated in Figure 2.

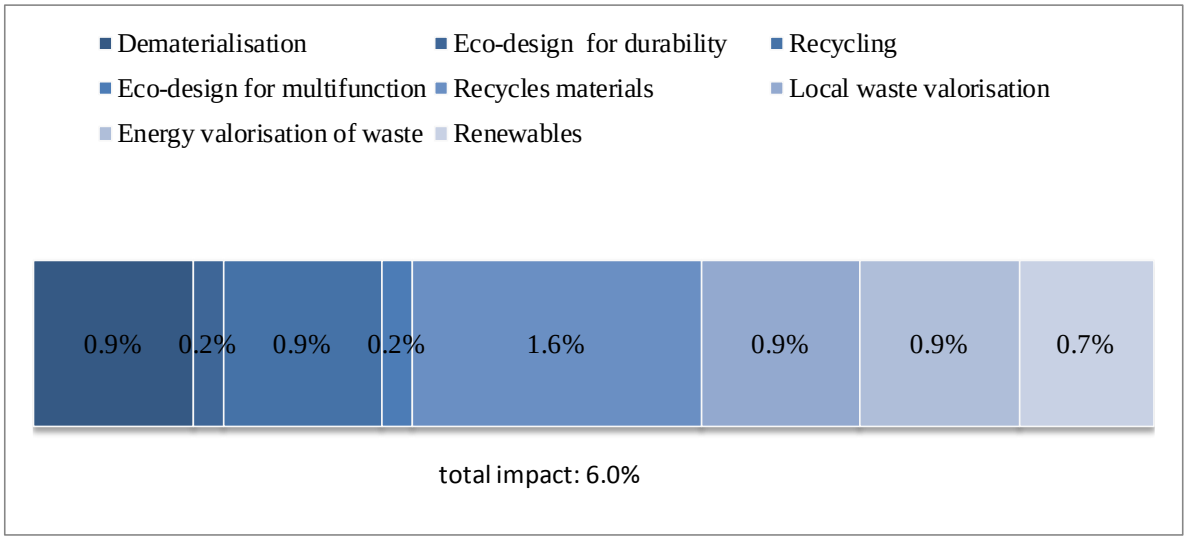
Figure 2. Implementation of the CE-related activities in the firms in the sample



In order to extrapolate the impact of the CE to the whole economy of the region, we have developed a specific methodology based on the data pertaining to each CE-related activity. Survey results, concerning both the number of activities carried out by each firm and the intensity with which they are implemented, have been normalised to a Likert value scale (0 = the activity is not being implemented; 1 = low implementation level; 2 = medium implementation level; 3 = high implementation level; 4 = very high implementation level). In order to determine what percentage of the firm's activity is connected with the CE-related processes, these values are added up and weighted according to their economic impact. It has been calculated that approximately 6% of the sample firms' activity is connected with the CE-related

processes, as illustrated in Figure 3. These results are in line with previous studies, for instance Portillo-Tarragona et al. (2017).

Figure 3. Estimate of the percentage of sample firms' activities related to the CE.



3.2 Impact at the territorial level

In order to analyse the impact of the CE at the territorial level, three basic socio-economic indicators are taken into consideration: turnover of firms directly or indirectly involved in the implementation of the CE; the number of jobs created by the CE-related activities; and, the consumption of raw materials, intermediate products and other supplies.

These calculations consider different levels of commitment to the CE-related activities; waste management firms are considered the most closely involved with the CE, and we must also emphasise industrial sectors which are likely to implement technologies specified in the BREF documents (what were referred to as 'sensitive' sectors). As noted, it has been estimated that approximately 6% of the sample firms' activity is connected with the implementation of the CE principles.

Currently, the gross effect of the implementation of the CE on employment can only be estimated with very limited precision (Horbach, Rennings, & Sommerfeld, 2015). We can measure the evolution of employment in the waste and recycling sectors, but changes undergone by professional profiles are hard to relate to the degree of dissemination of the CE model because these changes take place in already existing industrial sectors (Meyer & Sommer, 2014). Currently, the impact of the CE model in Aragón is being estimated on the basis of employment in the waste sector and the number of jobs in 'sensitive' sectors that are related to CE-related activities, calculated on the basis of the percentage of a firm's activity that is connected with these processes.

Based on the statistical-descriptive analysis carried out in this study, the impact of the adoption of the CE-related practices by firms at the territorial level is presented in Table 2.

Table 2. Estimate of the impact of the CE-related (directly and indirectly) activities in Aragón in 2017.

	Estimatel (for 2017 based on 2016 data)		
Area	Turnover (€ million)	Total jobs	Total raw material consumption (€ million)
All industrial sectors	25,842,114	89,832	13,017,067
Direct impact of the CE on waste management and recycling	352,858	3,623	77,381
Estimated impact the CE-related activities in 'sensitive sectors	1,244,199	4,315	593,298
Total estimated impact	1,597,057	7,938	670,679
% of overall industrial output	6.2%	8.8%	5.2%

These results suggest that the impact of the CE in Aragón is still limited in socio-economic terms, as only 6.2% of the overall industrial activity is in some way connected with the circular model, according to EU criteria.

In order to forecast the evolution of these indicators in the near future (5, 10 and 15 years), we need to identify the factors that could accelerate or slow down the implementation of the CE-related activities in the region. These factors need to be corrected by a coefficient λ_{CE} according to three different scenarios: business as usual, conservative forecast and optimistic forecast (Table 3).

The "business as usual" scenario would occur in a context of moderate upgrade of the factors that may improve the CE in the region, such as moderate increases in the price of raw materials and more availability of secondary raw materials, jointly with a moderate worsening in the supply of virgin raw materials.

Likewise, a moderate increase of the CE at regional level would respond to different factors such as an increase of the regional incentives for the CE, to limitations of the volume of waste to landfill or improved technological solutions for waste recovery. To replicate this scenario, the coefficient λCE would take a value equal to 1, so the expected variations for each of the above mentioned factors in the temporalis scenarios would not be modified.

In the optimistic scenario, the expected variations in each one of the temporal scenarios would be higher than the previous one, without the moderation on the factors that can foment the CE. In this case the variations are higher (λCE would take a value equal to 2), which would mean to increase the CE in the region to a greater extent.

This scenario would be considered if the region can lead a specific regional CE strategy to promote measures, tools and policies to foment the CE in different sectors and among society in terms for waste management, the development of voluntary standards, eco-innovation and eco-design, etc.

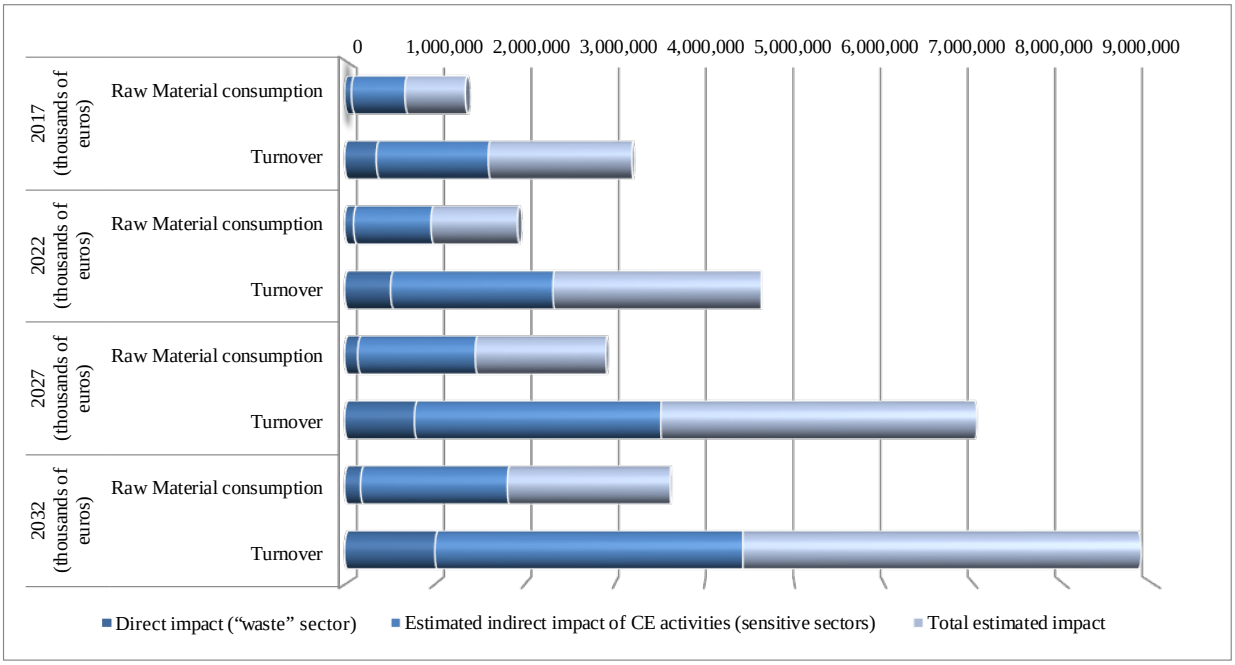
Table 3. Matrix of the CE factors and scenarios

	Circular Economy Scenarios								
Factors for the CE analysis	*Variation of scenarios (5, 10, 15 years)*			*Business as usual for a CE*		*Conservative scenario for the CE*		*Optimistic scenerario for the CE*	
	$M_0 + 5$	$M_0 + 10$	$M_0 + 15$	Evolution of factors	λ_{CE}	Evolution of factors	λ_{CE}	Evolution of factors	λ_{CE}
a) Price of raw materials and resources	0,1	0,2	0,3	moderate increase	*1*	Stable (as at present)	*0*	high increase	*2*
b) Availability of secondary raw materials	0,1	0,2	0,3	moderate increase	*1*		*0*	high increase	*2*
c) Availability of raw materials and resources	0,05	0,1	0,15	moderate decrease	*1*		*0*	high decrease	*2*
d) Stimulus of the regional CE	0	0,2	0,3	moderate stimulus	*1*		*0*	high stimulus	*2*
e) Limits to the regional volume of waste	0	0,2	0,3	moderate increase	*1*		*0*	high increase	*2*
f) Maturity of technology	0,2	0,3	0,4	moderate improvement	*1*		*0*	high improvement	*2*

On the contrary, in a conservative scenario the factors do not change from the initial situation (λCE would take a value equal to 0), and it would mean not to improve the CE in the region.

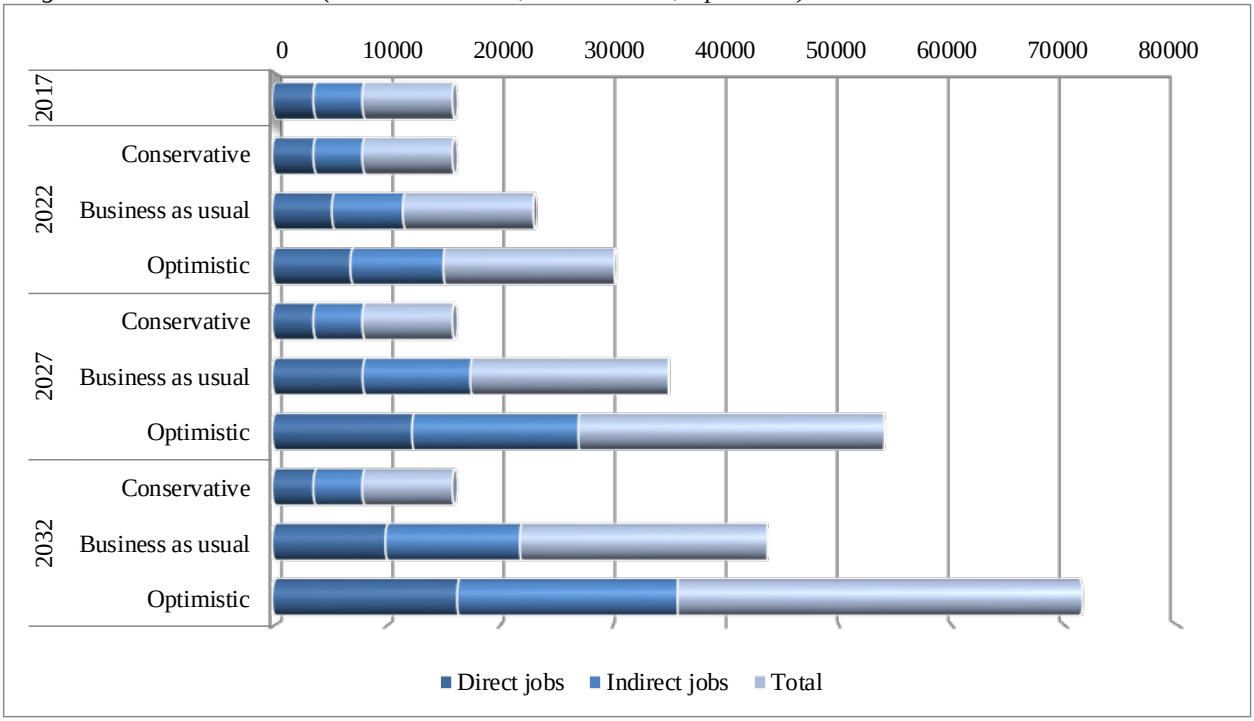
Figure 4 illustrates the results of these estimates for a 'business as usual' scenario, in terms of economic impact and raw material consumption.

Figure 4. Estimate of economic impact directly and indirectly related to the CE in Aragón:" business as usual" scenario.



In term of jobs, the CE is expected to have a moderate impact (8.8% of the industrial sector in the region for 2017). The forecasts are summarised in Figure 5, which presents the evolution of the CE-related employment in all three scenarios.

Figure 5. Estimate of the impact of directly and indirectly the CE-related activities on employment in Aragón in all three scenarios (Business as usual, Conservative, Optimistic).



Despite the limitations of this first approximation, it can be predicted that the impact of the CE on employment will increase in proportion to the growth of the recycling and waste management sectors. This growth is expected to generate new employment opportunities in these sectors. On the other hand, employment in indirectly the CE-related activities carried out within the framework of 'sensitive' industrial sectors is expected to require different professional profiles.

As such, we can conclude that the introduction of the CE-related activities in Aragón is still at an incipient stage. The sectors in which these activities are most widespread include design and the use of secondary raw materials (R1). As such, the socioeconomic impact of the CE on the industrial sector at the regional level is limited. In the future, this variable will be affected by the existing stimuli and barriers to implementation of the CE-related activities (R2).

Policy makers could promote tools and measures to promote the CE and other initiatives to facilitate the introduction of industry-driven and/or collaborative models (for instance, 'self-regulation'); the establishment of voluntary standards, especially concerning the management and valorisation of resources; and, the promotion of eco-design and manufacturing standards that stimulate the closing of materials loops.

Concerning the most appropriate measures at the current incipient stage of implementation of the CE-activities, we may emphasise the beneficial effects of the CE on: manufacturing processes, the value chain and cost structures; the promotion of neutral technologies that allow market access to new agents.

The main challenge that the implementation of the CE poses to private firms is that it requires changes in the business model, as well as the monitoring of flows of raw materials and resources, especially as the progressive introduction of increasingly far-reaching collaborative models is to be expected.

4. Conclusions

The adoption of the CE-related activities by businesses depends on the decisive implementation of a number of key measures at the regional level. These include the design of products, so their components and materials may be reused; the promotion of innovative business models for the collection of these components and materials; and, the implementation of reverse-logistics solutions, with the ultimate aim of reintroducing these components and materials into the supply chain. Definitely, initiatives to facilitate the adoption of these activities include the introduction of industry-driven and/or collaborative models (for instance, 'self-regulation'); the establishment of voluntary standards, especially concerning the management and valorisation of resources; and, the promotion of eco-design and manufacturing standards that stimulate the closing of materials loops.

In order to meet these targets and help firms in the transition towards circular economic models, favourable conditions must be created; in this endeavour, regions must play a relevant role. Policy makers can act as a driver for the adoption of the CE at a regional level by providing tools and measures to help companies to close material loops, to control their efficiency, and to invest in new technologies to adopt new CE-related activities.

Our micro analysis has included qualitative and quantitative variables in order to assess the level of dissemination of CE-related activities within a given territorial framework. In general, we may conclude that there is much room for improvement concerning in-house recycling, including energy extraction from waste, once other hierarchically superior alternatives have been ruled out or whenever this is advisable in terms of environmental balance. At the present time, overcoming the barriers that hamper the implementation of these actions depends on public stimuli. For the firm, the adoption of the circular model involves creating new environmental management systems, introducing changes in the cost structure, applying collaborative models, improving reporting practices, and undertaking financial adjustments. In this regard, firms are also heavily reliant on public incentives, especially those concerning the introduction of collaborative models, which are in turn critical for the closing of materials loops.

The main findings of this study concern the methodology used to measure the dissemination of CE principles in the private sector and their impact at the territorial level. Our conclusions lay the foundations for the internal measurement of circularity in private firms and for the assessment of the economic activity generated, in terms of investment and income. As such, these results are valid for academics, to further the conceptualisation and measurement of CE at the micro level; for practitioners, in promoting internal measurement and definition of CE-specific indicators, internal organisation and reporting; and for public administration, as an aid to policy-making and the development of CE-specific incentives.

The proposed methodologies and the highlighted measures could be used for decision making support in order to implement the CE solutions in regions and to influence setting up regional priorities. The limitations of this study chiefly concern the size of the sample, the number of CE activities analysed and the fact that the data comes from a single European region. Future research should try to overcome these limitations and reach a better understanding of the adoption of CE-related criteria and their impact at the territorial level.

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