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INNOVATIONS AND THE CIRCULAR ECONOMY: A NATIONAL AND REGIONAL PERSPECTIVE

Davide Antonioli [1,4], Elisa Chioatto [2,4] , Massimiliano Mazzanti [3,4]

[1,2,3] University of Ferrara – Department of Economics and Management (Ferrara, Italy), V. Voltapaletto, 11, 44121, Ferrara, Italy
[4] SEEDS Sustainability, Environmental Economics and Dynamic Studies, Italy

E-mails:[1] davide.antonioli@unife.it; [2] elisa.chioatto@unife.it; [3]massimiliano.mazzanti@unife.it

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Abstract. The introduction of innovative practices compatible with the objectives of the circular economy is one of the main enablers for transforming current production patterns towards more sustainable and competitive systems. Understanding whether and to what extent firms are introducing circular-oriented innovations allows monitoring where we stand in the circular transition and thus which further efforts are needed to achieve a resource-efficient economy. This study is based on data from two surveys on Small and Medium Enterprises: the first one reaches 4565 companies located throughout Italy (in the two-year period 207-2018) and the second one focuses on 1603 companies operating in the Emilia-Romagna region (in the three-year period 2017-2019). The analysis is aimed at offering a broad picture of the level of involvement of national and regional firms in the implementation of circular innovation. Despite the overall positive performance, there appears to be a fragmented adoption of circular innovation in terms of firms' size, technological intensity of the sectors and in accordance with the geography and the productive specialization of the territory. In general, circular innovation mainly involves firms operating in low-technology-intensity sectors in Southern Italy and more technological intensive sectors in Northern Italy and it is more widespread among large firms. On the contrary, in Emilia-Romagna, the distribution of circular innovation mainly concerns medium-sized firms, especially those belonging to low and medium technology-intensive sectors, moreover companies in the provinces of Modena and Parma show higher adoption rates.

Keywords: Circular Economy, Eco-Innovation, Circular Innovation, Small and Medium Enterprises, Business Models, Regional Studies

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Introduction

In the context of decoupling strategies (Mazzanti and Pronti, 2021) between economic growth and negative anthropogenic impacts on the environment (e.g. CO2 emissions), the Circular Economy (CE) represents one of the main pillars aimed at supporting the adoption and diffusion of innovation within the European Green Deal (Kemp et al., 2019). The envisaged framework of transition to emission-neutral economies, with the elimination

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of landfilled waste and overall low environmental impacts, poses crucial challenges for companies, which should embrace the CE objectives through the introduction of new processes and products (Barbieri et al. 2016). In order to make sustainability (e.g. circular business models) and competitiveness complementary, by turning the potential costs of more stringent environmental policies into competitive advantages, it is crucial to adopt environmental innovations along with organizational, technological and human resource management innovations (Antonioli and Mazzanti, 2009; Antonioli et al., 2013). This will allow creating complementarities aimed at increasing both social and environmental economic performances. Accordingly, in order to pursue the goal of competitiveness and sustainability, circularity should foster practices of participation and involvement of workers and stakeholders.

The concept of CE is indeed calling for the introduction of radically alternative business models compared to traditional linear modes of production and consumption. This transition will ensure the generation of profits and the maintenance of companies' competitiveness within the context of the increasing pressure to which production and consumption subject the global availability of resources. Price volatility, resource supply risks and accessibility to scarce materials have in fact become factors of great concern in order to continue to guarantee firms' competitiveness. In this scenario, the CE paradigm has been recognized as a high-potential solution capable of reorienting the traditional economic approach by changing the linear mindset of industry. In this model, indeed, resource conservation becomes the core of a new regenerative business approach, in which materials flow within a single closed loop. In this way, «the value of products, materials and resources is maintained in the economy for as long as possible, and waste generation is minimized» (European Commission 2015 p. 2).

As recognized in Bocken et al., (2016), firms can operate on several levels of circularity. The first is properly concerned with *closing material loops* through material recycling and/or recovery practices. The second level concerns *slowing material loops* through the production of more durable goods or the spread of reuse, repair and re-manufacturing activities. Finally, the third level of circularity supports the *narrowing of material loops* through more efficient and intensive use of resources and the replacement of material goods with immaterial services, which also involve consumer participation. Therefore, the design phase becomes the starting point for the development of products or services based on the principles of longevity, reuse/recovery, maintenance, recycling and dematerialization. In general, the goal is to develop new business strategies that create value based on minimizing material inputs, maximizing economic output, and respecting environmental limits (Flachenecker and Rentschler, 2019).

On the other hand, the transformation of conventional business models towards circularity cannot ignore the support of new technologies, processes and organizational structures. Maintaining current economic standards while decreasing resource use and waste accumulation requires innovation to play a key role in the circular reorganization of current production paradigms. In fact, innovation, and more specifically Eco-Innovation (EI), has been recognized as the catalyst for CE at the company level. The debate on EI has adopted different theoretical perspectives to better understand its features, dynamics, determining factors (Arundel and Kemp, 2009; Beise and Rennings, 2005; Berkhout 2011; Cainelli and Mazzanti, 2013; Marin, 2014; Jabbour et al., 2015) and its relation with the CE transition process (Cainelli et al., 2020). The traditional literature related to EI distinguishes between product, process, and organizational innovations, but concerning the link between EI and CE, Carrillo-Hermosilla et al., 2010 have most importantly highlighted the difference between incremental and radical forms of EI. Product and process EIs mainly represent technological solutions based on, among others, conservation and efficient resource management or design of long-lived, decomposable, repairable products. However, above all, achieving a new circular model requires systemic changes. Therefore, the introduction of non-technological EIs are necessary to promote new organizational models capable of inducing radical transformations within current production and consumption patterns. As pointed out in de Jesus et al, (2019) «merging technological and non-technological change into a new, cleaner techno-paradigm has been referred to as 'systemic EI' leading to the deeper promise of a circular transition». In this definition, EI is considered not only as

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an effective tool to achieve CE, but also as a vehicle for a higher level of sustainability, i.e. strong sustainability (Maldonado-Guzmàn et al., 2020).

It emerges that firms' ability to change current business models in a circular fashion way depends on their ability to make incremental and radical eco-innovations interact, in a context where incremental eco-innovations act as a tool to support more radical changes. In this view, circular EI is a combination of knowledge types driven on the one hand by R&D, cost reduction processes, and technical solutions embedded in cleaner products and processes, and on the other hand by new institutional organizations, business and behavioral models inscribed in circular organizational solutions (de Jesus et al., 2019, p. 1496). This shift is undoubtedly complex, hence it is important to assess the state of the art of the circular transition at the company level with the aim of identifying existing gaps, preparing solutions, and thus accelerating the action plan. This analysis needs to take place not only at the national level but especially at the local level. In fact, cities and regions have a central role in promoting CE because local and regional governments hold core competencies in most of the policy areas that underpin a circular change (e.g., waste management, water), and they are additionally more aware about the industrial network of their territory.

In this regard, the research center CERCIS of the Department of Economics and Management of the University of Ferrara, has conducted two surveys, at this stage, aimed at measuring the adoption of circular innovations in Italian and Emilia-Romagna manufacturing companies, with the aim of providing information and material for analysis and study to policy-makers and national and local stakeholders. This aims not only to raise awareness on the issue of circular innovations in companies, but also to provide a knowledge base that can be used to develop and design more conscious economic and managerial policies of green human resource management. The following paragraphs will show the distribution of circular innovations at the enterprise level, both on the national and regional territory, with a particular focus and disaggregation of innovations at the level of the Emilia-Romagna region.

Surveys on manufacturing enterprises: national survey and regional survey of Emilia-Romagna

The two surveys conducted at the company level have the following characteristics.

The national survey on manufacturing companies with at least 10 employees was conducted in 2020 by the survey company Izi s.p.a.. This survey was configured as a CAWI (Computer Assisted Web Interview) survey through which a structured questionnaire was administered to companies. This questionnaire is made up of 4 main macro-sections: Business Characteristics; Innovation and Investment; CE; Organization, Training and Industrial Relations. Within each section, an appropriate set of questions allows for the collection of relevant information on the various themes. Although the questionnaire is complex, the objective of interviewing at least 4500 companies at national level has been achieved: the sample of responding companies is 4565, stratified on three dimensions - geographical location (macro area, Istat), sector (technological intensity, Eurostat), size (10-49 employees; 50-249 employees; 250+ employees). The period covered by the national survey is the two-year period 2017-2018. For the national economy it represents a two-year period of growth, which had already begun in 2015, but which showed a phase of slowdown in the transition from 2018 to 2019 (albeit still growth).

As for the regional survey, in the Emilia-Romagna region, the characteristics are similar to the national one described above: a survey conducted by Izi s.p.a. through the CAWI method on regional manufacturing companies. However, several aspects significantly distinguish the regional from the national survey. First of all, the reference period is the three-year period 2017-2019; secondly, the investigated firms involve also micro enterprises (information was also collected for a limited sample of enterprises with less than 10 employees); finally, on the one hand questions on supply chain strategies have been added to the sections of the questionnaire and a new section on the impacts of the pandemic crisis (COVID-19: impact and strategies) has been introduced.

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On the other hand, the Organization, Training and Industrial Relations sections are not present. In the regional context, 1603 firms have been interviewed

Dissemination of Circular Innovations (CI)

In order to understand the diffusion framework of circular innovations (CI), we will lead an analysis on two levels, in accordance with data collected from the surveys: the national level and the regional level. On each macro level, we will provide information on the diffusion of CI along three dimensions: 1) the economic sector to which the company belongs, in terms of the technological intensity of the sector itself (Low technological intensity; Medium-low technological intensity; High technological intensity; Medium-high technological intensity)[*]; 2) the size of the company in terms of employees (under 10 employees only for the regional survey-Micro; 10-49 employees-Small; 50-249 employees-Medium; 250+ employees-Large); 3) the geographical localization of the company - regional in the analysis of national diffusion and provincial in the analysis of regional diffusion.

The national context

At the national level we represent the distribution of circular innovation defined as a binary variable CI for the biennium 2017-2018. If a company declares that it has adopted at least one innovation aimed at achieving one of the following CE- related objectives indicated in the questionnaire - Reduction in the use of water in the production process; Reduction in the use of materials; Use of energy generated from renewable sources; Reduction in the use of electricity; Reduction in waste emitted (per unit of output produced); Reuse of waste in the production cycle; Transfer of waste to other companies that use it in their own production cycle; Change in product design to minimize the use of raw materials (including energy); Change in product design to maximize recyclability; Change in production process to reduce greenhouse gas emissions - then the variable takes a value of 1. Otherwise it takes a value of 0. The average of this binary variable provides the percentage distribution. At the national level, about 43% of companies claim to have adopted at least one of the circular innovations indicated, with differences in the spread at the regional level, as emerges from Figure 1. In addition, it results that, despite some exceptions, CI tend to be concentrated in regions where the industrial sector weighs heavily on the regional total[†]. We can assume that these are 'driven' by both industry diffusion and manufacturing specializations within each region. However, we also need to consider the time dimension to which the questions about CI deployment refer: the 2017-2018 biennium. Since there are certainly asynchronies in the diffusion of CI, it is possible that some regions will be less innovative in that two-year period because responding firms were already very active in introducing CI prior to 2017-2018. On the other side, it is interesting, while waiting for new survey data on 2019-20, that we do not observe a fairly typical north-south divide in the rate of innovation, confirming that the country is on average at high levels of performance on circularity issues[‡]. On the other hand, we must also remember the Italian R&D deficit, still more than 1.5 GDP points away from the European target of 3% R&D per share of GDP, and almost 3 GDP points away from leaders such as South Korea. The effort over the next five years must be to raise private and public R&D, and specifically the number of researchers and graduate and highly qualified personnel in companies.

[*] https://ec.europa.eu/eurostat/statisticsexplained/index.php?title=Glossary:Hightech_classification_of_manufacturing_industries
[†] Source https://www.infodata.ilsole24ore.com/2014/11/26/la-mappa-delle-imprese-in-italia-scopri-la-vocazione-di-ciascuna-regione/?refresh_ce=1

[‡] https://ec.europa.eu/eurostat/web/circular-economy/indicators

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Figure 1. Distribution of circular innovation (CI) in the different Italian regions (4565 responding companies)
Source: National Survey, Cercis, 2020

As shown in the following figure (Fig. 2a,b), the distribution of the CIs seems to be linked to the technological intensity of the sector to which the company belongs, but in an opposite manner with respect to the context of the two Italies (Fig.3): North and South. Responding companies belonging to sectors with low and medium-low technological intensity are mainly concentrated in southern regions (Fig. 3). Within these sectors, in southern regions, the CI in the period 2017-2018 tends to be more widespread. In Southern regions, CI is not an issue for firms in technology-intensive sectors. On the contrary, low-tech sectors tend to be more sensitive to CI: this probably depends on the types of production processes and potential efficiency/cost gains that CI can bring to firms. On the other hand, by observing the companies' distribution in the North, we see that, to a relatively high diffusion of CIs in some regions, there is an associated low diffusion of responding companies in sectors with low technological intensity. Indeed, the greatest diffusion of CIs, in various regions of the North, characterizes sectors with the highest technological intensity, even though the diffusion in sectors with low technological intensity remains high. In terms of distribution by company size, we see that large companies are the most active in introducing CI.

The brief presentation of data on the distribution of CIs in the national context and their heterogeneity in terms of spread along the three dimensions analyzed opens the way to the analysis of distributional heterogeneity at the regional level.

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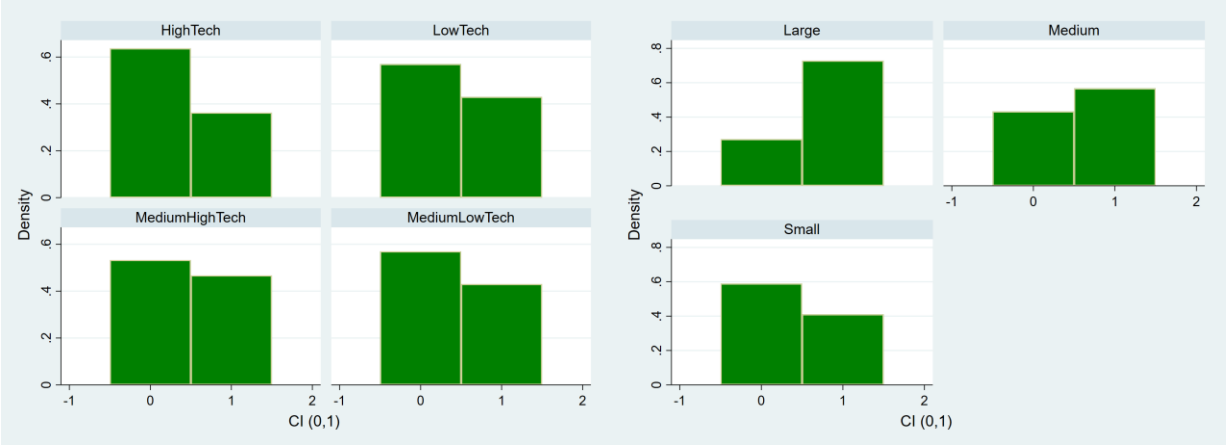

(a) **(b)**

Figure 2a,b. Distribution of CI by sector (based on technological intensity) and company size (based on number of employees)
Source: National Survey, Cercis, 2020

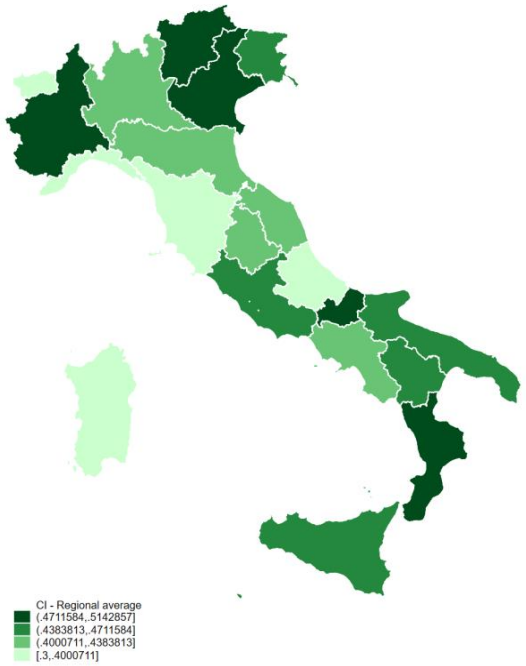

Figure 3. Distribution of medium-low and low-tech enterprises by region
Source: National Survey, Cercis, 2020

The regional context

As far as the regional context of Emilia-Romagna is concerned, we note that, the size variable has a different impact than in the national context, in terms of business characteristics that potentially influence the decision to adopt CI (Fig. 4). In terms of adoption, medium-sized companies have a performance similar to and, at the margin, superior to that of large companies. Therefore, it seems that in the regional context, medium-sized companies are more active than in the national context. This also happens for the introduction of other types of

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innovation (in particular, product innovation), leading to the hypothesis that the medium size, within the regional productive context, gives companies the ability to overcome both the inertia of large organizations and the difficulties generated by small size (e.g., scarcity of financial resources, difficulty in accessing credit). Specifically, data show that medium-sized companies, particularly those belonging to sectors of low to medium technological intensity, have introduced a higher percentage of circular innovations in the three-year period 2017-2019. These are followed by large companies, especially those belonging to sectors of medium-high technological intensity, and micro enterprises in sectors of high technological intensity. On the other hand, small enterprises are at the tail end, among which those belonging to medium-high technology intensity sectors stand out for the implementation of innovations related to CE strategies.

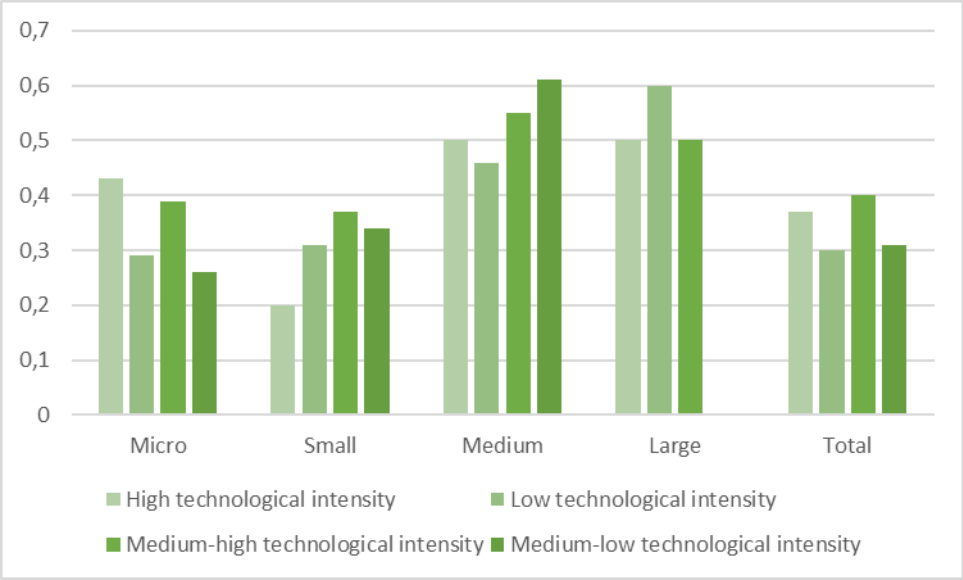

Figure 4. CI in Emilia-Romagna by sector (based on technological intensity) and firm size (based on number of employees) - 2017-2019 (1603 responding firms
Source: Survey regionale, Cercis, 2020

At the province level, the distribution of the CI variable shows the characteristics of Fig. 5. The companies that most frequently report introducing at least one CI in the three-year period 2017-2019 are situated in the provinces of Modena and Parma, then come Bologna and Ferrara followed by Rimini and Reggio Emilia. The provinces of Ravenna, Forlì-Cesena and Piacenza close the ranking. The national heterogeneity in the geographic distribution of circular innovations is also found at the regional level, when dividing the territory into provinces. Each province is characterized by specific production specializations and, in some cases, by industrial networks organized into districts (e.g. biomedical in the province of Modena).

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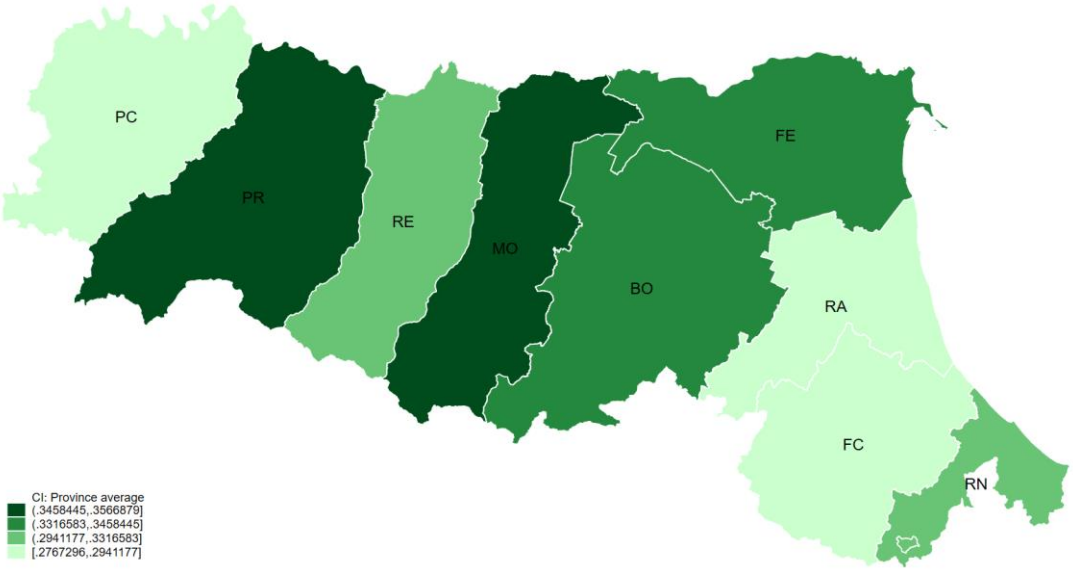

Figure 5. Distribution of circular innovation (CI) in the different provinces of Emilia-Romagna
Source: Regional Survey, Cercis, 2020

Turning to the specific types of CI (Reduction of raw materials; Waste reduction; Design for durability; Design change to reduce resources; Replacement with biomaterials; Design for reparability; Transfer of waste to other companies; Reduction of electricity; Use of renewable energy; Design for recyclability; Reuse of waste in the production process; Water reduction; Design for disassembly) we can notice the following in terms of distribution by sector and size (Figs.6,7). Out of the total number of companies responding to the survey, the main circular innovations introduced in the three-year period 2017-2019[§] are those aimed at the more efficient use of raw materials (13%), reducing the amount of waste generated per unit of output produced (9%), and changing products' design to increase the durability of goods and reduce the amount of resources needed (8%). Overall, in the introduction of these practices, medium- and large-sized companies and those in high- and medium-high-tech sectors stand out.

[§] To note, the total percentage of responding firms introducing individual circular innovations between the analysis by size and the analysis by sector is slightly different, as adopting the classification by technological intensity of the sector to which they belong loses some responding firms. Therefore, the percentage of circular innovations introduced by firm size is calculated on the overall sample of 1603 firms, while the percentage of circular innovations introduced by firms by sector is calculated on 1578 firms.

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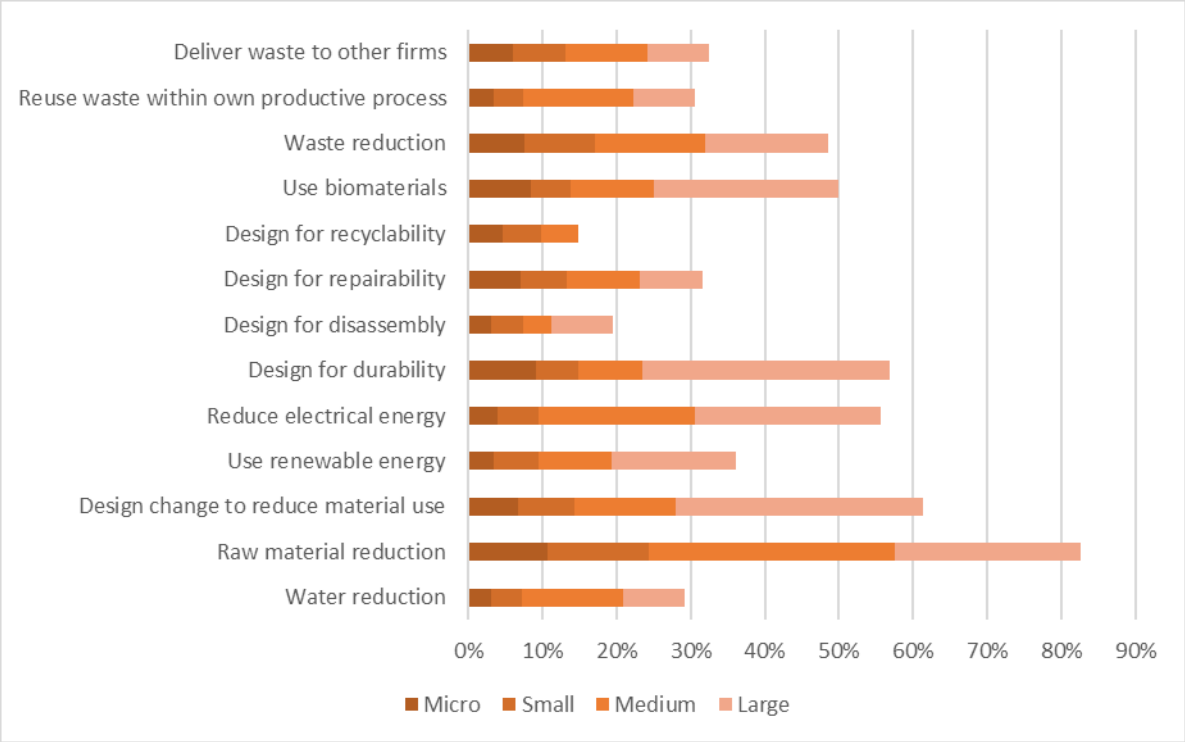

Figure 6. Distribution of the different types of CI by company size
Source: Regional Survey, Cercis, 2020

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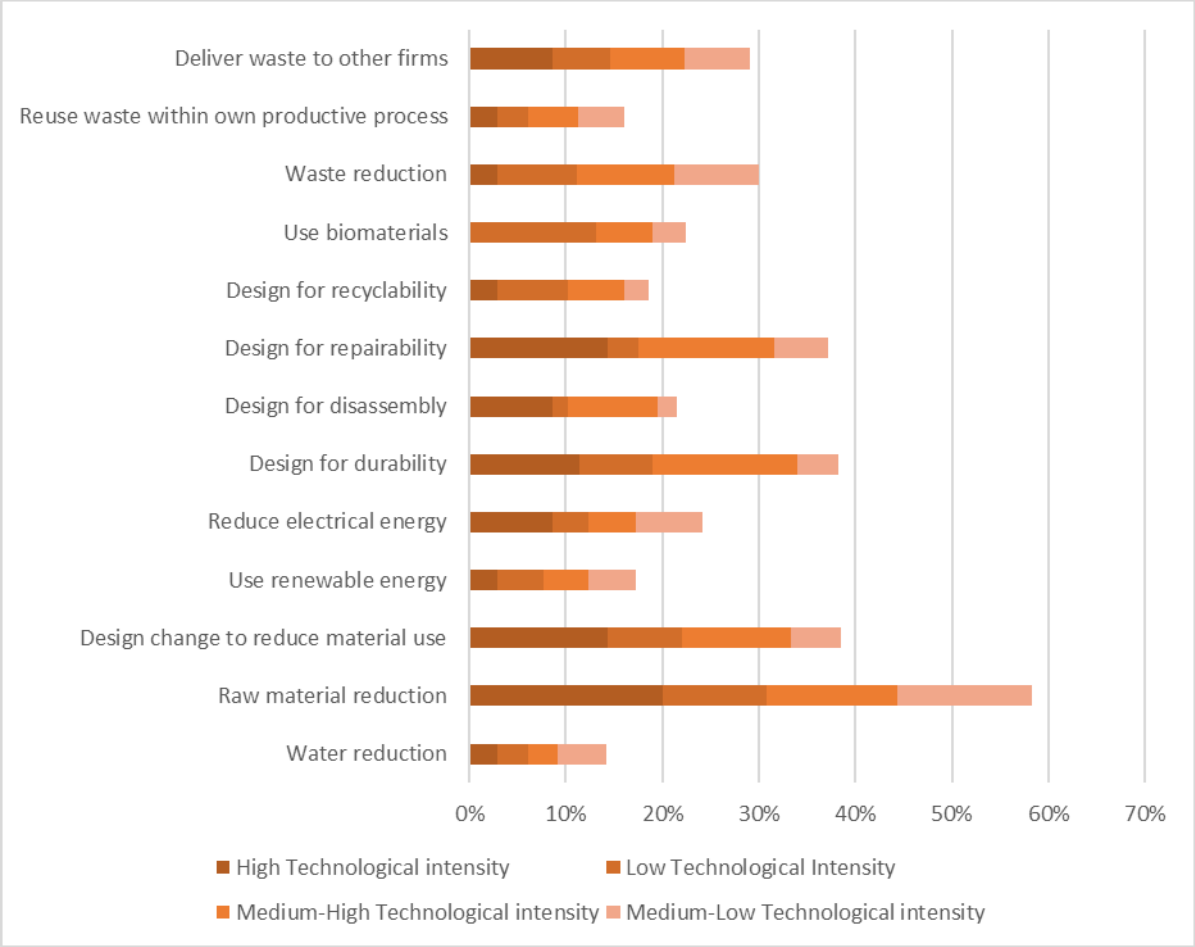

Figure 7. Distribution of the different types of CI by sector of the company (in terms of technological intensity)
Source: Regional Survey, Cercis, 2020

On the side of the geographic distribution of the CI types, we note that some provinces, including Ferrara along with Modena and Parma tend to have a higher diffusion compared to the average in terms of responding companies that declare adopting some of the various types of CI (Fig.8). To note that the average diffusion of CI in respondents is 6% and ranges from 15% for innovations aimed at reducing resources to 1% for design innovations aimed at improving disassembly and durability and for innovations aimed at reducing electricity. Modena has a much higher than average diffusion (gap of about 5%) on innovations aimed at reducing the use of raw materials, increasing reparability, reducing waste and transferring waste to other companies. Parma has a much higher than average diffusion (gap of about 5%) on innovations aimed at reducing the use of raw materials, increasing reparability and reducing waste.

Focusing the attention on the province of Ferrara, it emerges that, according to the sample of respondents, it is the province that has a much higher performance than the average (gap of about 5%) in terms of diffusion of CI with the following aims: to reduce the use of raw materials, to reduce waste, to increase durability, to change the design to reduce the use of resources, to replace existing materials with biomaterials. In the sample of respondents, companies situated in the province of Ferrara seem strongly active on a plurality of CIs aimed at different goals.

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Circular innovations	BO	FE	FC	MO	PC	PR	RA	RE	RN	Total Emilia-Romagna
Water reduction	4%	6%	3%	4%	11%	3%	3%	3%	5%	4%
Raw material reduction	15%	15%	7%	15%	9%	14%	10%	15%	12%	13%
Design change to reduce material use	8%	10%	5%	8%	4%	8%	7%	10%	6%	8%
Use renewable energy	5%	6%	4%	5%	6%	6%	3%	5%	6%	5%
Reduce electrical energy	7%	6%	1%	6%	4%	6%	5%	5%	9%	6%
Design for durability	8%	11%	4%	8%	4%	12%	8%	9%	5%	8%
Design for disassembly	3%	6%	4%	4%	2%	3%	4%	5%	1%	4%
Design for repairability	6%	7%	6%	10%	2%	10%	6%	6%	1%	7%
Design for recyclability	6%	7%	2%	5%	4%	5%	3%	5%	5%	5%
Use biomaterials	8%	10%	8%	6%	6%	6%	10%	7%	6%	7%
Waste reduction	9%	14%	7%	10%	7%	9%	8%	7%	9%	9%
Reuse waste within own productive process	4%	4%	2%	4%	4%	5%	7%	5%	6%	4%
Deliver waste to other firms	8%	6%	6%	9%	5%	4%	10%	4%	5%	7%

Figure 8. Percentage of responding companies that state they adopt the various types of CI by province
Source: Regional Survey, Cercis, 2020

Concluding remarks

The transition from a linear to a circular economy brings with it numerous challenges that companies cannot address without transforming the organizational foundations of their business. This research has focused on CI as a means of transitioning to CE. CI proposes an approach to closing resource cycles, which aims to overcome the limitations of the traditional economic paradigm based on the so-called take-make-dispose. The aim is to identify new models of production and consumption that ensure environmental protection without sacrificing economic growth priorities (Zoboli, 2018). It is an operational approach that integrates a number of strategies: from the minimization of raw materials and waste, to the extension of the life cycle of products, to the efficient use of resources, in which innovation plays a key role. Through the development of two surveys, at the national and regional level, this research focused on the level of implementation of CI among Italian manufacturing companies (in the two-year period 2017-2018) and Emilia-Romagna (in the three-year period 2017-2019). The objective is twofold, on the one hand to transfer and increase the knowledge of companies on the topic so that they can draw a competitive advantage from it, and on the other hand to provide data that positively affect the elaboration of conscious and appropriate economic policies.

The results of the survey showed that, on the national level, CI characterizes 43% of the responding companies. The spread is diversified according to the productive specializations of each specific regional territory. Moreover, while in the southern regions, CI mainly involves companies belonging to low-technology-intensity sectors, in the northern regions, it is mainly companies belonging to more technologically-intensive sectors that declare a greater introduction of CI. From the point of view of size, the distribution of CI is more widespread among large companies. On the other hand, at the regional level, the size variable shows that it is medium-sized companies that are more active in the adoption of CI. As in the national context, however, also at the regional level, the diffusion of CI and the implementation of the different types of CI differs according to the geography of the territory. The companies that most frequently have introduced at least one CI are found in Modena and Parma, while Ravenna, Forlì-Cesena and Piacenza are at the bottom of the list. Among the different types of innovation, those most introduced by Emilia-Romagna companies are aimed at more efficient use of raw materials, reduction of the amount of waste generated per unit of output produced, change in design to increase the durability of goods and to

reduce the amount of resources needed. Companies in the provinces of Ferrara, Modena and Parma are those that perform above average in the adoption of different types of CI. Specifically, Ferrara stands out positively from the average for the introduction of innovations aimed at: reducing the use of raw materials, reducing waste, increasing durability, changing the design to reduce the use of resources, replacing existing materials with biomaterials.

Overall, this survey therefore provides an exclusive picture of the state of the art of the circular transition at the firm level. This is a prerequisite for effective public policies to encourage and reinforce the ultimate implementation of this path of change. On the one hand, environmental, industrial, training and innovation policies must be integrated in order to pursue a broad sustainability that covers a large and interconnected number of SDGs, and on the other hand their design must be oriented both to support innovators towards increasingly radical processes and to help non-innovators get started. The goal is to bring the whole system of territories and sectors, micro, small-medium and large enterprises towards sustainability, through an ecological and fair transition, characterized by increasing investment in training and innovation in companies.

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Davide ANTONIOLI
ORCID ID: 0000-0001-5150-3714

Elisa CHIOATTO
ORCID ID: 0000-0002-9679-1163

Massimiliano MAZZANTI
ORCID ID: 0000-0002-6538-7942