Università degli Studi di Ferrara

Ph.D. Course

in

Economics and management of
Innovation and Sustainability

In cooperation with Università degli studi di Parma

CYCLE XXXV

COORDINATOR: Prof. Emidia Vagnoni

Circular Economy at the firm level*: how to operationalise the concept*

Scientific disciplinary sector SECS-P/02

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2019/2022

Abstract

To maintain current economic standards and halve resource use and waste generation, innovation must play a key role. The promotion of ecological innovations favourable to the circular economy is indeed considered a central element of the emerging circular transition. The aim of this thesis is firstly, to identify innovative circular-oriented practices able to guide current business models toward circularity , and second, to analyse how circular innovation can be implemented by firms. Specifically, on the one hand, the study will provide a theoretical framework on the interconnections between the concept of eco-innovation and circular economy, in order to shed light on the potential of eco-innovation in the realm of circular economy. A literature review was carried out to define the so-called Product life-Cycle archetype. This last consists of a categorization of a series of circular innovative practices, whose implementation supports firms in turning mainstream business models into a circular perspective. In turn, this has allowed the identification and categorization of circular business models, following a logic based on the product life cycle. On the other hand, this thesis will attempt to bridge the gap between theoretical research on circular economy and its application by identifying which factors can potentially facilitate/hinder the adoption of circular innovations by firms. In this regard, firstly, the role of social norms in firms' decision to adopt circular innovation was investigated, in order to explore whether peer comparison can play a role in firms' decision-making process. The analysis has been developed on a sample of 3270 Italian manufacturing firms (data have been collected by the Centre for Research on Circular Economy, Innovation and SMEs, Cercis, of the Department of Economics and Management, University of Ferrara in 2019), and the results of the econometric model show that considering peers having increased investment in circular innovation positively affect, on average, the likelihood of being a circular innovator. Secondly, a cluster analysis was developed on a sample of 1594 firms (Cercis data, 2020) situated in the Emilia- Romagna region (Italy) to identify and examine the distinctive features of circular innovators players in the Emilia-Romagna region. Taken together these findings may provide relevant insights, although not exhaustive, for the development of future national and local policies, in which governments may be interested.

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List of Acronyms

BM	Business Model
BMI	Business Models Innovation
CBM	Circular Business Models
CE	Circular Economy
CI	Circular Innovation
CSR	Corporate Social Responsibility
EFA	Exploratory Factor Analysis
EI	Eco-Innovation
ER	Emilia-Romagna
EU	European Union
GDP	Gross Domestic Product
ICT	Information and Communication Technology
MSs	Member States
R&D	Research and Development
RE	Resource Efficiency
RIS	Regional Innovation Scoreboard
SMEs	Small and Medium Enterprises

Introduction

The increasing awareness of the limits of the linear economy has determined the need to design a new economic organization that would provide the necessary well-being for more and more people without depleting the stocks of resources and increasing the quantity of waste in the environment. According to the European Commission indeed, by 2050, the *World will consume resources as if there were three*. As a consequence, over the next decades, global economies must reconsider how they create value in order to fulfil a decisive environmental impact reduction.

The promising substitute for the linear economy is the Circular Economy (CE), based on the idea of creating continuous cycles of resources, the CE will help to rebalance environmental debts and keep resource consumption within the earth's boundaries. This concept has gained increasing interest in the last decade. At the policy level, the EU Action Plan for a CE (COM(2015) 614 final) represents the first attempt to incorporate CE objectives into waste management systems. The promotion of a waste treatment hierarchy has been the first step to supporting the valorisation of waste as a substitute for the extraction of new resources to be used for the production of goods and consequently decrease the pollution caused by waste accumulation in the environment. The Package has proposed the revision of the main EU Directive on waste, namely Dir 2008/98/EC (waste), Directive 1999/31/EC (landfill), and Directive 94/62/EC (packaging). These last were definitively amended on the 30/5/2018 with the new Dir 2018/851, Dir 2018/850, and Dir 2018/852, which foresee more stringent and binding targets for waste collection and disposal. However, a full realisation of CE necessarily requires further effort, which regards the actual utilisation of recovered materials by producers and more generally a new system of product design.

This thesis represents the evolution of a research project that started during my Master's thesis [1]. This last was aimed at studying whether EU legislation on waste management was effectively encouraging the transition toward a sustainable management of waste, and in turn whether this had also positive effects in increasing the amount of secondary raw materials used in production systems. In nutshell, the purpose was to understand whether the transition toward sustainable management of waste, was also supporting the transition toward CE. A

[1] Further information can be found in the paper E. Chioatto and P. Sospiro (2022). Transition from waste management to circular economy: the European Union roadmap. Environment, Development and Sustainability. DOI:10.1007/s10668-021-02050-3.

qualitative analysis of the Circular Material Use rate[2] revealed that despite recycling rates were progressively increasing in all EU-Member States (MSs) examined, still significantly low amounts of waste were able to reach manufacture, hence reducing the need for virgin material extraction. From here the acknowledgment that more stringent waste management policies represented only half of the efforts needed to fully realise a CE and that targets and guidelines were also needed to strive for material use decoupling through new products' design approaches. This was confirmed by the New CE Plan (COM(2020)98 final), part of the broader project to make Europe the first climate-neutral continent by 2050, advanced by the 2019 European Green Deal. In this regard indeed, the EU emphasised the importance of utilising secondary raw materials, calling for greater involvement in the manufacturing system.

Against this background, the aim of this thesis is to study the operationalization of CE at the firm level, hence shedding more light on how CE strategies can be implemented by firms. The main proposition of this thesis, in accordance with the recent literature, is that Eco-Innovation represents a centre-piece of the emerging circular transition. Maintaining current economic standards while halving resource use and waste generation requires innovation to play a key role. Indeed, as pointed out in Barbieri et al. (2016) «moving towards a circular economy involves a rethinking of production cycles, production technologies, consumer behaviour and environmental policies, which are all factors that hinge heavily on the concept of eco-innovation » (Barbieri et al., 2016, p. 597). However, although the link between Eco-Innovation (EI) and CE is undeniable, a clear picture of the potential of EI in the field of CE is still lacking. Especially, an important question is which are the Circular Innovations (CIs) able to bring mainstream Business Models (BM) into the realm of CE? In turn, a theoretical definition of CIs would support the identification of new Circular Business Models (CBMs) that will emerge. Furthermore, not only it is important to provide firms with a theoretical basis from which to proceed, but it is also crucial to understand what companies need in order to cope with the transition, and fill the existing gap between the theoretical research on CE and its application. Consequently, another important issue to be addressed is what factors can facilitate the adoption of CIs in order for new CBMs to be effectively adopted.

[2] Ratio which measures «the share of material recovered and fed back into the economy–thus saving extraction of primary raw materials–in overall material use» (Eurostat, 2018 Circular Material Use rate: calculation methods).

Against this background, this thesis will proceed from the following two questions 1) Which CBMs emerge from the adoption of CIs? and 2) which are the drivers that favour the implementation of CIs?

The first chapter will explore the links between EI and CE and CBMs. Particularly, it is aimed at providing a literature review in order to recognize a theoretical definition for CI which serves the identification of new CBMs by means of what will be called the Product Life-Cycle Archetype.

The second chapter will be devoted to examining the role played by peer agents in firms' decisions to adopt CI. The study has the purpose to shed light on potential drivers that can motivate firms in the adoption of circular-oriented innovations. In this regard, by referring to behavioural economics' studies on consumers, this work will explore whether and to which extent peer comparisons can play a role also in firms' decisional process. For this purpose, an original dataset of 4565 Italian firms gathered by the Centre for Research on Circular Economy, Innovation and SMEs (CERCIS) is used to lead the analysis.

The third chapter will present the case study of the Emilia-Romagna (ER) region in order to identify different firms' profiles according to their level of innovativeness. The aim is to capture distinctive traits characterizing firms that decide to adopt CIs. Identifying and examining the key characteristics of circular firms can provide information on the tools they need to undertake the circular change. In this regard, the study will resort to a dataset of 1613 firms situated in the Emilia Romagna region collected by CERCIS.

CHAPTER	RESEARCH QUESTION	CONTRIBUTION
1	*Which Circular Innovations support the implementation of Circular Business Models?*	- Deepen current analysis on the relations between EI and CE - Provide a new categorization of circular business models according to different stages of products-life, by eventually allowing a clarification among the concepts of CE, EI, and CBMs
2	*Does the peer effect represent a driver for the adoption of circular innovations?*	- Shed light on potential non-conventional drivers influencing the adoption of CE-oriented innovation - Apply behavioural economic insights, traditionally studied at consumers' level, at firm level
3	*What do Circular Innovator firms look like in Emilia- Romagna?*	- Identification of key features of circular innovative firms in ER - Gather information on which characteristics seem to best suit the ability of firms to take a step toward circularity

1. Circular Business Models: defining innovations to boost Circular transition at firm level

1.1 Introduction

The prosperity the global economy has achieved nowadays, even if unevenly distributed, has come at high environmental costs, resulting in resource scarcity, biodiversity loss, climate change, and pollution, which are irreversibly changing the functioning of ecosystems' processes.

Global material use is expected to reach between 170 and 184 billion tons by 2050. This will be influenced first by the increase in population number, that by 2050 is expected to join 9.7 billion people, second by the expanding consumption trends; accordingly, 3 billion people are supposed to pass from low to middle-class consumption causing a 71% increase in per capita material use, and third by current unsustainable production systems based on take-make- dispose (Smart Prosperity Institute, 2020).

The current economic model not only surpasses the environmental capacity of providing new resources, but as the supply of finite raw materials and the regenerative capacity of renewable resources will be depleted, it will also lead to severe economic consequences, such as resource dependency, shortage, and price volatility. Therefore, decoupling economic growth from resource exploitation has become a challenge.

Taking inspiration from nature, a new circular economic approach is emerging, where materials constantly flow along with the system, and waste generation serves to secure new materials' demand. Within a CE, the design of products and processes is aimed at reducing material use, avoiding hazardous and polluting materials, increasing products' durability and maximizing their reuse and recovery. New models are therefore needed, founded on the creation of value through cycles of reuse, recovery, recycling, and putting the accent on functionality and services rather than ownership and material creation (de Jesus et al., 2018).

The reconfiguration of the current linear mindset requires transformative changes, i.e. «the process of breaking out to a sustainable and sustained trajectory of development» (de Jesus et al., 2018, p. 1495). Recent research has emphasized the pivotal role EI is going to play in the transition toward CE. Especially, EI has been recognized as key in the transformation of current production and consumption systems in a novel circular perspective, through the development of new technologies and forms of business.

However, despite the relation between EI and CE seems intuitive, the analysis of their interlinkages is still scant, with few studies showing the congruence between the two dimensions. *In which way and to which extent EI is instrumental along the CE pathway?* A more comprehensive study is, therefore, necessary to understand which innovative changes can influence such a paradigm shift, hence what CIs are. Identifying the role of EI and the link between CE and EI is essential to provide a definition for the specific realm of CI and support stakeholders to better address their actions. For instance, at the company level, ascertaining future direction will facilitate the overcoming of bottlenecks that hinder the adjustment of novel CE-friendly BMs. This work will consider the overlay between EI and CE as the point of departure for carrying out the potential of the transition to the circular economic paradigm.

The next sections will provide a view of the role of EI in driving pro-CE business models, by reviewing current academic contributions on EI and CE and highlighting their intersections. The objectives will be to: 1) providing a conceptual definition of CE and EI; 2) deriving a relationship between the two concepts at firms' level, hence providing a definition for CI (Section 1.2.); 3) generating a categorization of EI types that match with CE priorities, hence identifying CI in practice (Section 1.3); 4) providing an overview of the BMs categories that results from the integration of the different CIs types (Section 1.4).

1.2 Conceptual Background

1.2.1. The Circular Economy

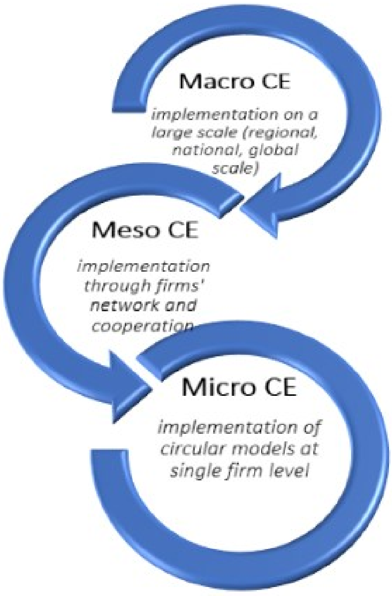
The concept of CE developed in the late 20th century from the emerging concerns regarding resources depletion (Kalmykova et al., 2018). The CE approach draws on several previous contributions. It builds on the tentative of overcoming the traditional *open-ended economy* (that surpasses *the* planet's limited capacities), referring to Boulding's idea of a *spaceman economy* (Boulding, 1966) and Daly's *steady-state economy* (Daly, 1992). Furthermore, CE shares the application of integrated productive paradigms with the notion of "industrial ecology" of Frosch and Gallopoulos (1989), by recognizing an analogy between the biological and industrial systems. These features can be found in the development of practices, such as industrial symbiosis, based on by-products exchange among firms. Later, during the 2000s, the CE has been associated with diverse notions, including product-life extension, material efficiency (Rashid et al., 2013), Cradle-to-Cradle (McDonough and Braungart, 2002), product- service systems (Stahel, 1982), clean production (Kalmykova et al., 2018; de Jesus et al., 2018; de Jesus and Mendonça, 2018). As a whole, the CE concept has its roots in different disciplines, and thus it «emerges today as a wide-ranging concept, and all these various contributions must be considered in their specific contexts» (de Jesus et al., 2018, p. 3002).

Against this background, despite the concept of CE has been broadly investigated, still, no commonly accepted definition exists (Lieder and Rashid, 2016). In Kirchherr et al. (2017) a set of 114 definitions of CE have been identified in the literature, which mainly embrace a combination of reducing, reuse, and recycling activities (p. 22). Many relevant definitions are published in form of strategic frameworks and initiatives from institutions, international organizations, or NGOs. For instance, the Ellen MacArthur Foundation recognizes CE as «an industrial economy that is restorative by intention; aims to rely on renewable energy; minimises, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design» (Ellen MacArthur Foundation 2013, p. 22). In turn, the European Commission has identified CE as an economy in which «the value of products, materials, and resources is maintained in the economy for as long as possible, and the generation of waste is minimised » (EC, 2015 p. 2). These contributions jointly concur in the identification of several core elements of CE, namely: a) minimization of resources' employment (material and energy), efficient use, and prioritization of renewable over hazardous materials; b) extension of products' lives through repair, remanufacturing, reconditioning and new BMs design; c) waste valorisation through recycling and network creation for by-products' exchange. In general, it emerges that the CE is an approach aimed at achieving an alternative model based on reducing resources' exploitation and waste generation, and developing a continuous recirculation of end-of-life materials.

Beyond this, many studies have highlighted that the CE concept has a broader scope, that compasses a more complex reconfiguration of industrial and consumption routines embedding the three dimensions of sustainability: environmental quality, economic prosperity, and social equity, as discussed in Geissdoerfer et al.(2017). This approach involves the implementation of several strategies aimed at reorganizing both production and social systems into «regenerative environmentally sound closed circuits» (de Jesus et al., 2018 p. 3004). Especially, CE belongs to the *strong* notion of sustainability (Dietz and

Neumayer, 2007), since «the emphasis is not on substitutability and aggregate capital, as in the neoclassical linear conception, but rather on the different logic behind the valuation of natural resources on the one hand, and manufactured capital on the other hand» (Martins, 2016, p. 32). Building on this definition, the CE transition is clearly a multidimensional process, which requires the interplay of systemic and radical changes from product design to waste management and the conversion of the linear socio-economic paradigm of consumption. In de Jesus et al. (2018) three levels of analysis have been presented for CE implementation. The *micro level* focuses on private companies through BMs based on eco-design, resources efficiency, cleaner production, and new production and consumption methods, The *meso level* concerning firms' interaction through the creation of networks e.g. industrial symbiosis. Finally, the *macro* level in which CE is addressed at the national or global scale through legislation (Maldonado-Guzmàn et al., 2020; de Jesus et al., 2018).

Fig. 1.1 Different dimensions of implementation of CE



Authors' own elaboration from de Jesus et al. (2018)

As for the micro-level, the focus of this study, the transformative process toward a closed-loop of materials is strictly linked to inter and intra-firms' ability to change their business practices through innovation as a vehicle to achieve it (López et al., 2019). Firms should embrace new business strategies able to produce a new value, based on efficient input usage and maintenance over time. This is heavily aligned with the United Nations Development Goal 12 of *Responsible Production and Consumption*, even though applications of the CE encompass most of the other UN development goals.

Products need, indeed, to be planned with CE awareness in their entire life cycles (Lieder and Rashid, 2016). The first priority is analysing the types of materials used for manufacturing. In this sense the CE concept complies with the idea of cleaner production aimed at eco-efficiency, avoiding pollution and waste production. The second priority regards products' usage, which should be directed toward a progressive *de-use* (less consumption), *re-use* (less disposal), and more radically toward a performance economy, where ownership is replaced by access (de Jesus et al., 2019; Stahel, 2010). The third priority addresses the evaluation of products' obsolescence, hence how to manage materials at the end of products' life. This calls, on the one side, for new infrastructures able to bring materials back in order to be reprocessed and returned to production processes for secondary purposes. On the other, it requires new and sustainable waste management systems aimed at incentivizing the circularity of materials «by strengthening the link between waste treatment and resource recovery» (Cobo et al., 2018 p. 282). Waste management has indeed so far involved for the most end-of-stream solutions, differently in a CE, consumed products should be valorised by prolonging their lifetime or through the reintegration of valuable materials into manufacture. This can be achieved following the waste hierarchy priorities, hence by detaining the value of products in the upper stages through reuse, refurbishing, remanufacturing, and recycling over landfilling and incineration disposal practices.

CE is therefore, here considered as an integrative concept for guiding a sustainable development that conciliates environmental preservation with socio-economic performance. The multi-level framework of CE is analysed from the *micro* perspective, with particular emphasis on firms' ability to re-direct production systems towards new BMs based on the minimization of resources' extraction and maximization of resources' use and waste valorisation.

1.2.2. Eco-Innovation

Despite transitions inherently require innovation-intensive processes, these last not necessarily translate into a status quo improvement from welfare or sustainability perspectives (de Jesus et al., 2018; de Jesus and Mendonça, 2018). The 20th-century idea of progress has indeed been dominated by a technological regime founded on intensive carbon use and resource extraction, which has led to undesirable environmental and ethical consequences. The connection between environmental challenges and innovation has been firstly addressed in the early 1990s. As the attention to the environment became part of the political agenda, a growing branch of the literature has emerged linking innovation to environmental concerns and providing diverse but connected definitions. In de Jesus et al., (2018) different terms have been distinguished, such as "sustainable innovation" addressing both ecological and social concerns, "environmental innovation" more addressed to environmental benefits, and "green innovation" related to improved products/processes for higher environmental sustainability, “business model innovation” regarding the way firms do business to maximize social and environmental benefits.

As for EI, one of the main accepted definitions is those provided by the Measuring Eco-innovation Project, which defines EI as “*the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives*” (Kemp and Pearson 2007, p. 7). Besides environmental improvements, EI has also been recognized as an opportunity for economic growth for firms that are willing to increase profits while addressing environmental preservation (Andersen, 2008). For example, EI can favour firms’ growth through potential cost reductions, arising from renewed and most efficient processes, decreased risks of resources’ price volatility, and increased market share of environmental products (Demirel and Danisman, 2019). In turn, Carrillo-Hermosilla et al., (2009) have widened EI’s impacts on overall sustainability dimensions. They indeed pointed out that, EI enhances environmental performance, but also «economic and social impacts play a crucial role in its development and application and hence determine its diffusion path and contribution to competitiveness and overall sustainability» (Carrillo-Hermosilla et al., 2009, p. 8).

Drawing on the different definitions, OECD (2009) has considered EI on the basis of three main dimensions: types of innovation (*targets*); the nature of the modifications produced (*mechanism*); and the induced effects (*impacts*). As listed in **Table 1.1** different typologies of EI exist, namely product/service, process, and organisational, marketing methods, and institutions (Carrillo-Hermosilla et al., 2010; OECD, 2009). So far, in Horbach (2008) technological innovation is also clearly distinguished from non-technological innovation, this last can indeed include institutional, organisational, and social innovation. Recent literature has indeed shown that EI is more than green technologies implementation, rather it may represent the enabler of overall green operations. Lastly, EI can be defined depending on the impact produced on environmental conditions. The effects of innovation can indeed vary from incremental, aimed at modifying or enhancing existing technologies or process to increase the efficiency of material or energy use; and radical innovations that involve changes in the enabling technologies of an economy modifying the overall technological regime (Carrillo-Hermosilla et al., 2010). Hence, building on de Jesus et al. 2018 definition

EI is here considered as any innovation that: 1) has positive environmental impacts, while delivering social and economic enhancements; 2) results in new or improved products, services, organizational schemes through technological and non-technological processes; and 3) is incremental or radical.

Table 1.1 EI typologies

*Eco-innovation **target***	*Eco-innovation **mechanism***	*Eco-innovation **impact***
Product/service	Technological	Incremental
Process		
Organisational		
Marketing methods	Non - Technological	Radical
Institutions		

Authors' own elaboration from OECD (2009)

All different dimensions of EI, extensively presented in Barbieri et al., (2016), interact and exert a different influence in the transition towards CE. For this reason, a better understanding of the linkages between EI and CE is needed in order to make these concepts applicable and operational at the company level and help firms moving away from the linear economic model.

1.2.3. The link between Eco-Innovation and Circular Economy

In later years research has been growing around the theme of CE as an operational concept. However, still scarce understanding exists on the procedure allowing a circular transition, especially, on how to achieve it through EI (de Jesus et al., 2019), which in last instance poses the question of what CI is.

Many authors jointly recognize EI as a vehicle for companies to undertake the CE pathway. However, both due to the emergent circular concepts and lack of data on the application of CI at the firm level, innovative practices for the CE are still vaguely defined in the existing literature (Demirel and Danisman, 2019). This thesis is therefore aimed at shedding light on EI activities and their existing relationship with the CE at the firm level. This study, therefore, attempts to shed light on the issue by addressing the existing gap on the link between EIs and CE practices. This will eventually allow identifying how EIs act as a mediator to induce new circular business patterns.

As recognized in de Jesus et al., (2018) and de Jesus et al., (2019) neither every EI is linked to CE nor every CE dimension needs innovation. In addition, not every EI has the same impact on the development of CE. Hence, it is necessary to understand which types of EIs are compatible with CE and to which extent.

EI and CE intersections can distribute horizontally, according to EI targets, mechanisms, and impacts (de Jesus, 2018; Vence and Pereira, 2019) or vertically according to the micro, meso, and macro levels of CE. Taking as example de Jesus et al., (2018) categorization and merging it together with Vence and Pereira (2019) insights, **Table 1.2** combines both vertical and horizontal intersections in order to explore how each dimension of EI crosses each level of CE.

Table 1.2 Intersections between EI typologies and CE dimensions

<table>
<tr><th></th><th>Eco-innovation
target</th><th>Eco-innovation
mechanism</th><th>Eco-innovation
impact</th></tr>
<tr><td>Macro Circular Economy
implementation on a large scale (regional, national, global scale)
Role of policies and regulation</td><td rowspan="3">Product/service
Process
Organisational
Marketing methods
Institutions</td><td rowspan="3">Technological
Non - Technological</td><td rowspan="3">Incremental
Radical</td></tr>
<tr><td>Meso Circular Economy
implementation through firms' network and cooperation
Industrial symbiosis, green supply chains</td></tr>
<tr><td>Micro Circular Economy
implementation of circular models at single firm level
Eco-design, cleaner production, new circular business models (services over product)</td></tr>
</table>

Authors' own elaboration from de Jesus et al., (2018) ; Vence and Pereira (2019); OECD (2009).

This thesis will specifically examine the interlinkages between CE and EI at the micro level. At this stage, EI particularly refers to incremental modifications of products and services. Nonetheless, also more radical changes are necessary, in order to bring *status quo* transformations into current production patterns (de Jesus et al.,2018).

Technological EIs are especially introduced at the micro level to address the priorities of RE and eco-design. According to Demirel and Danisman (2019) cleaner production is a *process EI*, which focuses on the rearrangement of operational process, technologies, or practices aimed at minimizing resource or energy use in order to achieve better efficiency within the organization. On the other side, eco-design refers to *product EI*, which includes the use of benign materials, the creation of longer life cycle products, or the new products category (Demirel and Danisman, 2019). Indeed, as de Jesus et al. (2018) suggests, eco-design aims at designing products with lower environmental impact by considering the whole life cycle. For example, goods are designed caring for quality, durability, constant upgrades, re-manufacturing, or replacement of defective parts. In Maldonado-Guzmàn et al., (2020) both product and process EIs have been found to exert a positive influence on CE. Indeed, as for product EIs, they are considered excellent solutions to minimize resources' and energy exploitation, while process EIs favours the introduction of technological transformation in productive operations. As a consequence, product and process EIs represent practical solutions that allow the operationalization of CE priorities ranging from resources' conservation, to efficient resources' management as well as product design focusing on life extension.

Notwithstanding, above all CE advocates for radical changes that, as anticipated in the previous section, make the concept fall under the *strong* version of sustainability. In this sense, the introduction of non-technological EIs is necessary to promote new organisational models able to induce more systemic transformations in current production and consumption patterns. As pointed out in de Jesus et al., (2019) fusing technological and nontechnological change into a new cleaner and more congruent techno-paradigm has been referred to as "systemic EI" which leads to the deepest promise of a CE transition. Not simply regarding resource use through technological EI, but system re-design favouring the emergence of new behavioural rules hence new model of business. In this definition, EI is considered «not only as one of the most effective tools for achieving CE but also as the path through which a higher level of sustainability can be achieved» (Maldonado-Guzmàn et al., 2020, p. 4). In addition, adopting a holistic approach results important also to avoiding the negative impacts of some apparently sustainable practices. For example, some green technologies are built upon rare materials or long-lasting products that rely on materials difficult to recycle (Vence and Pereira, 2019). In light of this, eco-innovative efforts, of product or process, must converge in a most complex innovative process able to create new circular systems that produce overall positive environmental, economic, and social impacts.

Under these premises, companies can accomplish the passage from linear to circular production models by relying on EI. Particularly, through the combination of technological and non-technological EI, with gradual EI acting as a tool in support of more radical changes. EI can power the development of new product, process, that address the flowing of resources in loops of reuse, recycling, and renewal (De Jesus & Mendonça, 2018) as well as the development of new organisational models (products' dematerialization, use over own, pay per use, and so on) (de Jesus et al.,2019). The first approach relies on gradual changes in the attempt to transform the entire system. For instance, it is mostly based on progressive eco-innovative efforts at the product, process or a combination of the two that favours system-wide impacts. Differently, the second approach tries to radically provide systemic change. In this last conception, besides value creation, business has to include also value recovery through resource optimization and preservation (Vence and Pereira, 2019). In this view, «transformative" pro-CE innovation is thus a Schumpeterian new combinations of "harder" (R&D-driven products, cost-cutting processes, technical solutions embedded in cleaner products and processes) and "softer" types of knowledge (the institutional setups, BMs and the behavioural patterns inscribed in circular organisational and marketing solutions)» (de Jesus et al., 2019, p. 1496). This transformation builds therefore on the involvement of a plurality of actors i.e. policymakers, business, institutions) (de Jesus et al.,2019).

1.3 Research Methodology: from Circular Innovations to Circular Business Models

1.3.1. Categorization of Circular innovations

After having clarified the existing links between CE and EI, and a definition for CI, the next objective is to identify which specific eco-innovative practices (of product, process, and organisational) support the achievement of CE priorities at the firm level. These last will indeed allow companies to bring incremental or radical changes within their BMs and support the redefinition of their managerial choices towards CE.

In this regard, recent contributions have been reviewed in order to select CE-oriented innovative practices. **Table 1.3** presents a categorization of identified measures. Originally, this study groups circular practices according to the different stages of products' life, hence in correspondence with the three main CE priorities. *Input-based* practices concern strategies acting on the way products are manufactured and production processes are carried out; *use-based* practices affect product delivery and usage; *end-of-life-based* practices influence products' management after the consumption phase. On the whole, *input*, *use*, and *end-of-life-based* practices are a mix of product, process, and organisational EIs, concerned with technological and non-technological improvements, capable to induce respectively incremental and radical modifications within firms' model of business. To note, these practices are not necessarily related to Business Model Innovation (BMI), but rather they are concerned with a novel conception of business coherent with CE, likely to stimulate overall business innovation.

Table 1.3 Circular innovation practices

Main category	Example of Circular innovation	Related Literature
Input-based practices	Use Renewable Energy Use bio-based, biodegradable, compostable materials Use Recyclable materials Reduce material/energy use per same output Use secondary raw materials Design for durability Design for reliability Design for trust Design for repair/remanufacture Design for upgrade Design for dis-reassembly Design for compatibility	(Bocken, et al. 2016) (Ellen MacArthur Foundation, 2015) (Lewandowski, 2016) (Nußholz,2017) (Diaz, et al., 2019) (Salvador, et al., 2019) (Van Renswoude et al., 2015) (Ünal et al., 2019) (Guldmann, 2016) (Heyes et al., 2018) (Søgaard J. and Remmenb, 2018)
Use based practices	PSS lease Product renting PSS Product rent or pooling PSS performance based Product sharing Product co-ownership Virtually access	
End-of-life based practices	Upgrading Remanufacture Repair Upcycling Recycling Energy recovery from non-recyclable waste Supply of waste materials Reverse logistic	

Authors' own elaboration

Under these premises, moving to a CE at the micro-level includes factors such as new technologies, process, and organisational structures able to re-orient conventional BMs' trajectories toward CE. In this regard, the next sections will clarify to which extent CI acts as a catalyst for BMs' reconversion by identifying and classifying which CBMs may emerge from the introduction of CIs.

1.3.2. Defining Circular Business Models

EI represents a crucial value-added for businesses willing to move towards CE. CE expects the decoupling of resources exploitation from output creation as a means to prevent environmental damages while guaranteeing profit increase. To this extent, firms must essentially be eco-innovative in order to become circular, especially if they need CI in order to model their business in a circular perspective (Pieroni et al., 2019; Salvador et al., 2020). However, despite the growing body of literature around these themes, still, no conceptual consensus exists around the notions of *business models*, *business model innovation*, and *Circular Business Models* (Evans et al., 2017), and their interception.

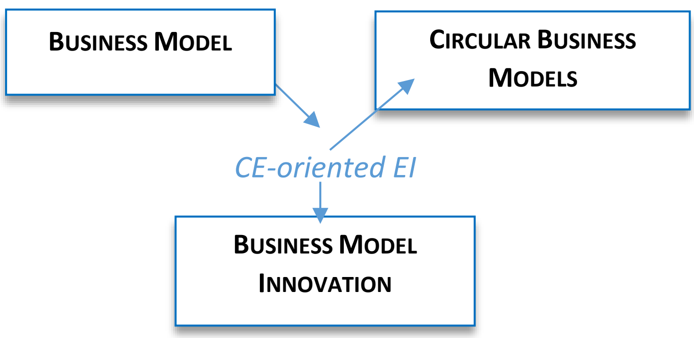
The concept of BM became popular in the 1990s. Since this time, hundreds of articles have been published to define the term. In general, BM refers to the *value proposition*, *value creation, delivery*, and *value capturing* of an organization (Geissdoerfer et al., 2018). In a nutshell, BM denotes how an enterprise does business by transforming resources into economic value. The most widely used tool to frame BM is the BM Canvas, a methodology proposed by Osterwalder and Pigneur (2010) to visualize and express the main business concepts in nine blocks: key activities, key partnerships, key resources, value proposition, customer relationships, channels, customer segment, cost structure, and revenue streams.

Parallel to this literature, the notion of BMI has received increasing attention over the past 15 years. The latter refers to single or multiple changes in BMs components, which ensure a new way of creating, delivering, and capturing value (Bocken et al., 2018). For this reason, BMI is considered the enabler of innovative product/process and structural changes within organizations, which further represents firms' source of competitive advantage (Pieroni et al., 2019).

Recently, a growing number of studies have direct concerns about the analysis of BMI in the specific area of CE. However, the literature related to the synergies between the concepts of BM, BMI, and CE is still young and poorly explored. Several authors e.g. Lewandowski (2016); Nußholz (2017); Merli et al., (2018); Pieroni et al., (2019); Rosa et al., (2019) have mainly focused on the theoretical systematization of these concepts. On the other hand, Bocken et al., (2016); Geissdoerfer et al., (2018) have examined how CE priorities can be operationalized at the BM level. From a CE perspective, companies need to change their mindset: they «need to think in systems around products and reinvent how they can generate revenue by creating and maintaining value over time» (Bocken et al., 2018, p. 81). Although this process is intended to create positive organisational and environmental impacts, CE-oriented BMI can be associated with a high level of uncertainty and complexity. Accordingly, authors such as Tura et al., (2017); Linder and Williander, (2017); Evans et al., (2017); Salvador et al., (2020) have analyzed the main barriers and drivers that respectively hinder and foster CBMs implementation. Finally, since differences between economic sectors require a different application of CE-oriented innovations, few authors have guided an empirical analysis around CE-BMIs, among others Ünal et al., (2019); Bocken et al., (2018); Heyes et al., (2018).

From this it emerges that the analysis of how the CE can be incorporated within companies' BMs through BMI has been mainly developed at a conceptual level, neglecting on the other hand the importance of in-depth practical research (Pieroni et al., 2019). Furthermore, despite multiple attempts to create comprehensive conceptual archetypes, there is still no common framework for defining, designing, and implementing CBMs. It seems that the rapid expansion of this research and multidisciplinary contributions have created confusion and ambiguity in the interpretation of BMI and its synergies with CE. Against this background, this thesis will try to address these shortcomings and cover the existing gaps. This work considers CE innovative practices listed in **Table 1.3** as the innovative efforts allowing firms to bring incremental and radical changes, hence innovation within their BMs, in line with CE. BMI eventually enables them to achieve a new circular way of doing business, therefore new CBMs. As a consequence of this process, a new classification for CBMs is identified.

Fig. 1.2 Interlinkages between the concepts of BM, BMI, and CBM through the implementation of CE- oriented EI



Authors' own elaboration

1.4 Results: the creation of the Product Life-cycle Archetype for CBMs identification

Doing circular business involves transforming the source of profit from selling goods to maintaining value in use (Bocken et al., 2016). Thus, in a CBM profit is derived from the flow of materials and products over time through the introduction of innovative strategies. This thesis will distinguish linear BMs from closed-loop BMs through a new classification. In the existing literature, several authors have classified CE practices that support BMI to achieve circular models in different ways. For example, Bocken et al., (2016) identify CBMs based on changes in resources' flow i.e. *slowing*, *narrowing* and *closing* resource cycles, and Ellen MacArthur Foundation, (2015) derive CBM implementation from a series of circular actions i.e. regenerate, share, optimize, loop, virtualize, exchange (Ellen MacArthur Foundation 2015). This thesis instead will follow a logic based on the product life cycle. In fact, starting from the list of practices in **Table 1.3** three main groups of CBMs are identified: BMs based on circular input, BMs based on circular use, and BMs based on circular output. The results of our effort are represented in **Table 1.4**.

Table 1.4 Circular innovations and CBMs: the Product Life-Cycle Archetype

Main category	Circular business model	Example of measures
Circular input	Cleaner Production	Use Renewable Energy Use bio-based, biodegradable, compostable materials Use Recyclable materials Reduce material/energy use per same output Use secondary raw materials
	Extended-life span Production	Design for durability Design for reliability Design for trust
	Second-life Production	Design for repair/remanufacture Design for upgrade Design for dis-reassembly Design for compatibility
Circular Use	Product-service systems (PSS)	PSS Product renting PSS Product renting or pooling PSS performance based
	Collaborative Consumption	Product sharing Product co-ownership
		Virtual access
	Product dematerialization	
Circular Output	Second life for products	Upgrading Remanufacture Repair
	Second life for materials	Upcycling Recycling (Downcycling) Energy recovery from non-recyclable waste
	Take back management	Supply of waste materials Reverse logistic

Authors' own elaboration

1.4.1. Business models based on circular input

CE must start with the design of new products. Not only do companies need to choose less impactful materials (i.e. Cleaner Production), but above all, they need to apply new priorities for products' usage (i.e. Extended-life span Production) and optimize the impact of products' waste (i.e. Second life-Production). This means thinking about the end from the beginning. In particular, this approach is consistent with the CE literature that refers to McDonough and Braungart's (2002) "cradle to cradle", supporting the idea of considering products as if they will never become waste.

Cleaner Production is based on the selection of safe resources, their efficient use, and the exploitation of value derived from waste. In this type of activity, companies select resources with less environmental impact that guarantee the same performance and materials that allow the closure of resources' flows (e.g. bio-based materials, biodegradable, compostable, recyclable). In this regard, Bocken et al., (2016) distinguishes between biological and technological cycles. On the one hand, goods produced with safe materials can be converted into nutrients for the natural system at the end of the product's life. On the other hand, the production of goods with technical nutrients involves the use of resources that can be continuously recycled and used for new goods because they maintain equivalent properties. In addition, *Cleaner Production* includes the development of new processes that can generate the same amount of output while reducing the use of necessary raw materials, and replacing virgin materials with secondary raw materials.

BMs focused on ***Extended-Life Span Production*** include designing long-lasting and high-quality products. The goal is to produce durable goods that guarantee long use before breaking down. It is therefore a matter of designing reliable artefacts that provide users with the warranty of long-time functionality without deteriorating. In addition to technical obsolescence, these BMs also address the problem of emotional obsolescence. This concerns the production of goods capable of arousing feelings of emotional attachment in the consumer, who will therefore be led to lengthen the phase of use and postpone the discarding of the finished product and the purchase of a new model. This type of business prefers quality, justified by higher prices, rather than cheap products aimed at mass consumption and characterized by programmed obsolescence.

Second-Life Production considers the end phase of products and their impact from the design stage. Not only do manufacturers focus on providing long-lasting products, but they also provide services that support the restoration of discarded goods or components. This activity can overlap with Extended-Life Span Production, however, while the latter is exclusively about creating durable artefacts, Second-life Production primarily focuses on planning how to give them a new life. Indeed, manufacturing high-quality/high-performance products, which ensure durability, also incentivizes reuse, repairing, upgrading, or remanufacturing. However, on the other hand, some firms may decide to directly provide after-sale support or services (e.g. reparability, maintenance, warranty) as part of their business (this is linked with the Extended Producer Responsibility applied in the EU to many products e.g. electronic), or additionally to create interchangeable products' components, which can be used after product decay. This process is supported by designing for disassembly/reassembly.

1.4.2. Business models based on circular use

In recent years, it is possible to recognize a growth in ***product/service-based BMs*** that are aimed at the transformation of goods in favour of services. Consumers pay to access services that guarantee the use of material products without owning them (use-oriented) or to exploit their functionalities for a limited period of time (result-oriented). Therefore pay per use, or pay low period fees for access represent new paradigms that replace the traditional pay per ownership. Product leasing, renting, pooling, and pay-per-service constitute some examples of services offered by these BMs. On the other hand, as pointed out in Linder and Williander (2017) and Salvador et al., (2020), the retention of product ownership by producers facilitates the circular return of product and material flows. This in turn encourages practices of repair, remanufacturing, upgrading, and recycling.

Similarly, the business of ***Collaborative Consumption*** is linked to the sharing or renting of products or services, where customers share the full use or the payment with other customers. According to this logic, it is for example possible to benefit from homes, cars, and offices without necessarily being owners. These BMs are developed in a context of sharing products and services consistent with the emerging concepts of "sharing economy" or "co-ownership", which, however, is still little practised (Rosa, et al., 2019).

In the last instance, companies can provide alternative products' usage through ***dematerialization***. In these concerns, the absence of physical products is compensated by virtual access to services that guarantee the exploitation of the same experiences. This is the case with streaming media services, used to watch films or to listen to music.

1.4.3. Business models based on circular output

The realization of the CE requires the existence of two supply chains: forward and reverse (Antikainen and Valkokari, 2016). The establishment of return flows can be achieved with the support of new BMs concerned with the direct management of the post-use phase and the reintegration of whole products, components, and materials in the production phase.

On the one hand, companies can develop BMs aimed at providing a ***Second-life for Products.*** Hence, acting as third parties, other than manufacturers, they institute maintenance services to guarantee the reuse of damaged products' otherwise discarded. This includes upgrading, remanufacturing, and repairing activities.

On the other hand, companies can establish business practices that guarantee a ***Second-life for Materials***. These activities are both focused on recovering valuable materials within wasted products (e.g. through upcycling, recycling, recovering energy from non-recyclable waste) and selling it into the market (e.g. through the supply of waste materials).

Lastly, BMs based on ***take-back management systems*** are responsible for connecting the output phase with the input phase. These activities are crucial to ensure the success of the CE. Products, components, and materials must in fact necessarily travel the reverse route and return toward the beginning of the life cycle to be reused, remanufactured, and recycled. For this reason, in addition to the collection, reverse logistics systems are also needed Lewandowski (2016).

Box 1.1 – CE-innovative practices implementation in Emilia-Romagna firms

Considering the lack of in-depth practical research which examines how firms are strategically reorganising their traditional business models through CE-EIs, an investigation has been conducted on a small selection of firms situated in the CE region. A series of video interviews, using a questionnaire of eight questions, has been organised and directed to eight local companies in 2019. The purpose is first to understand firms' awareness of the emerging CE and sustainable priorities, and second, to verify their involvement, hence understanding whether and to which extent they introduced innovative practices to fulfil a new circular mindset. The innovations that responding companies reported having introduced, have been framed within the Product Life-Cycle Archetype, with the extent to investigate the main areas of intervention within firms' BM.

Firms are distributed in different sectors, namely wood, fibreglass, agribusiness, packaging, and FM transmitters, afterwards main firms' characteristics are reported:

24Bottles: settled in Bologna, it produces water bottles and coffee cups reusable, extra-lightweight, leakproof, and of design;

Schiassi: belonging to the packaging sector, it is specialised in the production of high-performance corrugated cardboard boxes as well as boxes customised, in the Bolognese area;

Macè: belonging to the canned fruit industry, produces fresh food with innovative processes that exclude pasteurisation, preferring treatments at a temperature lower than 12°C.

Iperwood-Novowood: part of the sector of wood-related producers, has developed in collaboration with the Faculty of Materials Engineering of the University of Ferrara, a new Wood Plastic Composite (WPC) formula.

Elenos Group: belongs to the broadcast sector, it is a world leader in manufacturing innovative FM transmitters;

Vetroresina: situated in the Ferrarese area, it is specialised in the production of fibreglass reinforced plastic panels;

CPR system: operates in the packaging sector and it is specialised in the production of reusable and recyclable packaging solutions.

The interviews' results are shown in **Table B1.1. Table B1.1** reports that respondent firms have mainly introduced CE-innovative practices aimed at achieving cleaner production and the extension of products' lifespan. Some firms are also involved in take-back management activities, indicating that business is positively moving in the direction of closed loops of products and materials. However, none of the respondents has reported the application of BMs focused on circular use. This may derive from a series of factors. In the first instance, not every type of business has the possibility to decline the physical usage of its goods, or to translate its supply into services. Furthermore, circular use especially requires the active participation of consumers and their availability to renounce to material ownership. These models require, indeed, changes in traditional purchasing and consumption patterns which can lead to demand uncertainty and can therefore contribute to firms' resistance toward their adoption.

Table B1.1 Intersection between firms' practices and Product Life-Cycle Archetype

CBM/Firm name		24 bottles	Schiassi	Mace'	Unigra'	Iperwood-Novowood	Elenos Group	CPR System	Vetroresina
Circular input	**Cleaner Production**	Avoidance of plastic usage in favour of reusable bottles	Use of recycled materials for cardboard boxes production	Exclude products' pasteurization to save energy	Use of oil waste and other agri-food residuals to produce biogas	New Wood plastic composite made with 70% recycled wood and 30% recycled polyethylene	Creation of a machine that collect multiple performances in an unique device	Use of recycled materials deriving from its products	
	Extended-life span Production	Selection and test of materials that ensure durability and reliability				New Wood plastic composite has better performances in terms of durability, mechanical strength than wood and in absence of harmful substances, such as PVC	Easily removal of damaged segments and their substitutability		
	Second-life Production						Easily removal of products' segments that favour product disassembly and repair		
Circular use	**Product-service systems (PSS)**								
	Collaborative Consumption								
	Product dematerialization								
Circular Output	**Second life for products**					Products can be pressed and extruded again up to 20 times without adding other components			
	Second life for materials							Unusable packaging is re-granulated and re-printed for a new distribution cycle	
	Take back management			Delivery of organic waste for methane production				Unusable packaging is returned to production phase	Re-introduction of industrial waste, discarded fibereglass products, and non-thermosetting materials into the production process

1.5 Conclusion

This study has attempted to shed more light on the links between CE and EI, with the aim to understand how to put forward the strategies of CE in practice at firm level. First, starting from the definition of CE and EI, the study has discussed the interlinkages between the two concepts, which lead to the identification of the definition of CI relying on de Jesus et al., (2019). Secondly, building on this theoretical background, the study has identified in the literature a series of innovative practices that support CE application and has categorized them according to products' life stages of input, use, and output. This eventually allowed to recognize and cluster the CBMs through the so-called Product Life-Cycle Archetype. Although not comprehensively, this study aims to contribute to the research concerning the implementation of CE strategies at the firm level, through CBMs. Indeed, creating more pronounced theoretical boundaries (*the what*) is a key step in understanding *the how* firms can effectively participate in the circular transition.

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2. Peer effect at the firm level in the introduction of Circular innovations

2.1. Introduction

One of the main factors determining the transition toward CE is the implementation of eco-innovative practices with a particular emphasis on EI related to CE. Despite the consensus around the conceptual boundaries of CI is still scant, this study will refer to the definition provided by de Jesus et al., (2019), which considers CI as «a combination of knowledge types driven on the one hand by Research and Development (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 behavioural models inscribed in circular organisational solutions» (de Jesus et al., 2019, p. 1496). Furthermore, not only a uniform methodology for integrated assessment of CE in the EI realm is lacking but also evidence of the main factors driving the introduction of CE-oriented innovations remains scarce. Recently, de Jesus et al. (2019) have focused on CE barriers stressing their impact on CI adoption, whilst Cainelli et al. (2020) have examined the role of policy and green markets in supporting the adoption of EIs compatible with Resource-Efficiency (RE). However, as for the traditional literature on EI, these studies have been primarily concerned with the most typical drivers behind firms' decisions to innovate i.e. 'Market-pull', 'Technology-push', and 'Regulation push-pull effect' (Rennings, 2000; Horbach, 2008; Horbach et al., 2012), disregarding the role played by "sources of information and knowledge used in eco-innovative activities" as Horbach et al. (2013, p. 528) have recognized.

Notwithstanding, including social effects, has increasingly been considered pivotal in providing a more comprehensive understanding of firms' decision-making. For example, recent research on firms' decision-making in financial policy (i.e. Gyimah et al., 2020; Park et al., 2017; Francis and Kostova 2016; Liu and Wu, 2015; Chen and Ma, 2017; Tang et al., 2019) have demonstrated companies openness to external sources of information, especially deriving from their peers. According to these results, indeed, companies evaluate the appropriateness of current behaviours or future actions by comparing themselves to their peers. It emerges that, despite it is widespread the idea that firms not operating in oligopolistic markets make their decisions without considering the strategies adopted by other firms, these studies showed that the behaviour of peer agents is able to influence firms' choices. This originates under certain circumstances of bounded rationality, such as in competitive environments or in situations of uncertainty, in which firms try to cope with their limitations by imitating competitors' characteristics and actions. On the other hand, Wu et al., (2020) have demonstrated that social comparison does not spread between random peers, but particularly, *nudging* firms operating in the same industry with information about their peers' actions positively increases the effectiveness of environmental policy instruments. These findings open the way on potential application of behavioural economics insights, generally examined at consumers level, to firms' action.

Against this background, the aim of this paper is to bridge gaps on the levers for CIs adoption on the one hand and to exploit behavioural economic insight to consider more complex-decision spaces for firms, on the other. More specifically this study assumes the existence of imitative tendencies during firms' innovative decision-making processes, by recognizing the social norm of the context in which companies operate as a crucial driver for CIs. Despite the existing literature provides several contributions on the role of inter-firm/cluster linkages, knowledge/technology spill over, and firms' openness to external sources of knowledge in positively affecting EI adoption, there is no evidence on whether firms compare themselves to peers to introduce CIs. For this scope, this paper will resort to behavioural economics concepts to investigate whether peers' behaviour positively affects the adoption of CI. By providing new insights within the literature on CI adoption, this paper will make a step further since it will extend the investigation of EI determinants beyond traditional market and regulatory instruments to social context and social relations. In doing this, it will originally transpose behavioural economics theory in the analysis of firms' decision-making.

The chapter is structured as follows. Section 2.2 provides an introduction to behavioural economic theory, in which social norms and comparisons concepts and their implications on human decisions will be highlighted. Afterwards, recent studies verifying peer influence at the firm level are considered. This will lead to Section 2.3 in which the effect of social comparisons at the firm level is examined both through descriptive statistics and econometric analysis. Section 2.4 will present the empirical results. Section 2.5 concludes.

2.2. Conceptual Background

2.2.1 Social norms and comparison influencing consumers decision-making: the case of environmental protection

Behavioural science' studies[3] have revealed that individual choices are far from being perfectly rational and selfish. People, indeed, systematically go wrong, and this makes them *human* beings rather than *oeconomicus* beings (Thaler and Sustain, 2008).

Evidence has revealed that sometimes people are willing to sacrifice their own self-interest to choose more fair outcomes. Indeed, they tend to reciprocate equitable actions and punish inequitable actions imposed by others. In addition, people are loss averse and attached to their habits, hence they greatly evaluate the utility loss to give up than the utility loss to receive. Sometimes, human beings also discount the utility from present to future and make choices that are not in their long run interest. Again, people are not good to assess risks and sometimes are unrealistically optimistic.

From a standard economic standpoint, these actions cause individuals to reduce their welfare, in its traditional interpretation of efficient resources allocation. However, this represents a natural attitude rather than a mistake. Human behaviour, indeed, naturally diverts from selfish and rational decision-making because there exist also social and cognitive factors influencing human choices that the standard economic framework does not capture alone. Behavioural studies have indeed proven that people are also motivated by others' well-being, perceived fairness, social norms, the context in which people live, and limited rationality. Hence, it emerges that, on the one side, individuals' cognitive ability constrains human problem solving, on the other side, human actions should be also associated with moral costs. People are indeed intrinsically motivated to achieve a good self-image and extrinsically motivated to receive a social appraisal.

As for the theory of social influence, the way people conceive the context in which they live affects their behaviour, and often this perception originates from how people compare to others. This conception finds its origins in the theory of social comparison in Festinger (1954) according to which individuals tend to evaluate the correctness or incorrectness of proper abilities and beliefs by comparing them with those of others, and in particular with

[3] It refers to three overlapping fields – cognitive psychology, social psychology, and behavioural economics (Sustein,2020).

others that are not extremely divergent from them. This happens because, besides wealth maximization, people derive utility also from doing the right thing or complying with moral. The fact that an action is not commonly accepted or practiced may inflict additional costs for undertaking such behaviour (Levitt and List, 2007). People do care about their reputation and self-image, hence they will interpret the external environment and behave in order to pursue or reinforce a good social status (Johansson-Stenman and Martinsson, 2006). It follows that a social normative influence can be identified behind human behaviour: humans are influenced by other humans, and, as reported in Thaler and Sustain (2008) this occurs in two different ways. On the one hand, *people learn from others*, therefore, if the majority acts or thinks in a specific way this suggests which is the right way to behave or believe. People may follow a practice without conscious reason, except that most people do it. According with Cialdini et al. (1990), this tendency refers to the *is* (descriptive) meaning of the social norm, which indicates what the majority does, and therefore what is perceived as "normal". In this way, subjects by recognizing and imitating the emergent conduct can «usually choose efficiently and well» especially in unfamiliar situations. Note that, this may happen even when a norm is not current yet, but it is emerging, as Sunstein (2020) reports «when people learn that other people are increasingly engaging in certain behaviour, they are more likely to do it, even if it has not yet attracted majority support (Sunstein, 2020 p.21). On the other side, Thaler and Sustain (2008) recognize that individuals feel the pressure of their peers. People care about what other people think about them, and therefore they act to conform with the group, in order to avoid disapproval. This exemplifies the *ought* (injunctive) meaning of the social norm, hence what is morally acceptable, which motivates the individual to act in order to avoid the burden of social sanction.

The central tenet is that these traits not only affect human decisions but also market outcomes, and as a consequence due to their predictability they can be exploited to correct market failures such as in the case of

environmental protection. The environment is a public good, governed by the principles of non-rivalry and non-excludability. As such, selfish and rational people are led to free ride when they benefit from an environmental service, and monetary incentives can correct this behaviour. However, the failure of homo oeconomicus assumptions opens the way to the possibility of exploiting individual non-selfish and non-rational motivation to foster pro-environmental conducts. Indeed, by knowing the factors that influence certain behaviours, it is possible to condition human choices by modifying the *architecture of choice* (Thaler and Sunstein, 2008).

Against this background, since individuals decide and conform to their conduct by using peer norms as standards, policymakers can exploit instruments such as social norm information and social comparison to increase the effectiveness of traditional market levers and direct individuals' choices towards more beneficial social behaviours. Accordingly, the positive impact of these non-pecuniary interventions, recognised as nudges, has been confirmed in many fields such as organ donation, charitable actions, and environmental preservation. Nudges represent one of the main tools used among the *behavioural toolbox* (Sustein, 2020), and as defined by Thaler and Sustein (2008), a nudge is «any aspect of the choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives. To count as a mere nudge, the intervention must be easy and cheap to avoid. Nudges are not mandates. Putting the fruit at eye level counts as a nudge. Banning junk food does not» (Thaler and Sustein, 2008, p. 6).

In the environmental domain, studies on the use of nudges i.e. pro-conservation messages, social norm information, and comparison have successfully demonstrated to promote consumers' environmental conservation. "Nudges" are able to change people's attitudes by simply making them aware of what other people are doing in similar situations (Costa and Kahn, 2013). Evidence of the efficacy of descriptive norm information can be found in (Goldstein et al., 2008) according to which hotel guests are encouraged to reuse their towels when they learned that most people participate in the water conservation program, and adherence is reinforced in accordance with the increased level of perceived similarity with other guests and their identification in a reference group. The effect of inter-group solidarity and intra-group competition have been specifically emphasised in Nomura et al. (2011) which found out how providing feedback to households about their street recycling rates (the reference group) compared to others produces a sense of identity and positively impacts recycling behaviours. Sometimes the power of information disclosure and feedback has been found greater than market mechanisms, such as in Allcott (2011) who demonstrated how informing households about their energy use compared to that of similar neighbours and that of efficient users not only induces energy conservation but also leads greater energy reduction compared to traditional tools. Nudges based on social comparison have been found to be effective also in the case of water conservation, as pointed out in Ferraro and Price

(2013). In addition, given the apparent short-run effect of non-pecuniary strategies, in Bernedo et al., (2014) has been provided empirical evidence on the persistence of social comparison effects after years. These studies highlight that nudges, providing information on own and peers' consumption behaviours, are therefore able to change people's welfare because they influence individuals' moral payoff. (Allcott and Kessler, 2019).

Individuals want to conform to social norms not simply when their actions are visible (reputation motivation) but also when their behaviour is not observed by others, in order to maintain a positive self-image (Johansson-Stenman and Martinsson, 2006). Delmas and Lessem (2014) distinguish, indeed, among an intrinsic motivation behind conservation behaviours and reputation reasons. The authors investigate the effect of private and public information disclosure. While in the first instance, giving information about others' energy use modifies people perception of what is moral (e.g. people feel guilty when they know their usages deviate above from the average), public information makes behaviour visible hence, in this case, energy conservation will be motivated to gather green reputation benefits.

2.2.2. Peer comparison influencing firms decision-making

As shown above, researchers have already extensively demonstrated that consumers' choices are influenced by social norms and comparison. Having reached this point, it is reasonable to question what happens to companies, that is whether and to which extent firms consider their peers during the process of decision-making, especially for innovation adoption.

To better investigate this research question, different strands of the literature have been linked. First, this work is concerned with research contributions on the incentives for firms to introduce EI. Recent analysis has extended the investigation of EI determinants, besides traditional market-pull, technology push, and regulatory push-pull effects (Horbach, 2008; Horbach et al., 2012), by examining the role of agglomeration economies and network relationships (Cainelli et al., 2012), knowledge-sharing and knowledge transfer (Ghisetti et al., 2015), organisational and human resource practices (Antonioli et al., 2013). Especially, latter findings open the way toward *open modes* of innovation, considering companies not only as isolated agents but also as elements that are part of social contexts. Secondly, this study will refer to research contributions confirming the existence of peer effect in firms' decision-making. Studies on peer influences go back to Di Maggio and Powell (1983) which have shown that firms belonging to the same business line are subjected to forces that lead them to become more similar to one another. More precisely, same conditions push rational organizations toward homogeneous forms and practices. What is relevant, is that this process of isomorphism has been recognized to partially derive from an imitation mechanism, which actually suggests that firms look at other firms to emulate their behaviours under certain circumstances. More recently, researchers have demonstrated the existence of peers' imitation for diverse decisional process as *investment banking* (Chen and Ma, 2017), *corporate financial policy* (Gyimah et al., 2020; Tang, et al., 2019; Park, et al., 2017; Francis, et al., 2016; Kaustia and Rantala, 2015; Liu and Wu, 2015), *R&D investments* (Kelchtermans et al., 2020), and *environmental-based policies* (Wu et al., 2020).

These studies provided evidence that firms refer to their peers' behaviour when they formulate decisions, especially in highly competitive environments. For example, in corporate decisions, Gyimah, et al. (2020) postulate that the trade credit policies of peers are able to influence a firm's own trade credit policy. In turn, Liu and Wu (2015) suggest that when Corporate Social Responsibility (CSR) is considered a competitive tool, the behaviour of firms is positively affected by the CSR level of their competitors. This is consistent with the results in Chen and Ma (2017) and Gyimah et al., (2020) which highlight that firms imitate others either to maintain their market position or to cope with rivals' actions, consistent with the rival-based-theory. On the other side, the more uncertain the environment in which firms operate is, or the more ambiguous the goals of an organization are, the greater the extent to which a firm perceives imitation to be a successful strategy. Indeed, according to the results in Gyimah et al., (2020), Chen and Ma (2017), and Francis et al., (2016) the peer effect proceeds from a leader-follower relationship, as suggested by the information-based literature. Follower firms are those with low market share, low liquidity, and low profitability, more generally, those lacking market experience and resources. In these situations, learning from peers that possess superior information helps small firms building their reputation and avoiding investments' uncertainty. Moreover, in Kelchtermans et al., (2020) is found evidence that in situations of uncertain information, for example, due to the complexity of public R&D support measures, social interactions do not spread among random peers, but rather among firms characterized by preferential connections, particularly those active in the same industry.

It is worth highlighting that, for the scope of this study, the term "*peer*" indicates firms competing in the same market and sharing similar characteristics, rather than firms situated on different levels (e.g. leader-follower), Wu et al., (2020) have indeed proved that providing firms with information on decisions made by their *similar,* through social comparison or aggregate peer actions, is able to increase the effectiveness of environmental policies in case of firms' heterogeneity. The results suggest that companies align their decisions with peers not only for strategic reasons, but also according to social pressures.

Table 2.1 Peer effect evidence at company level in the literature

Evidence on Peer-Effect (When?)	Related literature	
Competitive markets	*Gyimah et al., (2020)*	Trade credit policies of peers influence a firm's own trade credit policy
	Liu and Wu (2015)	The behaviour of firms' is positively affected by the Corporate Social Responsibility level of their competitors.
	Chen and Ma (2017); Gyimah et al., (2020)	Firms' imitate others to maintain their market position or to cope with rivals' action,
Uncertain situations	*Gyimah et al., (2020)* *Sikochi (2020)* *Chen and Ma (2017)* *Francis et al., (2016)*	Firms lacking of market experience and resources by learning from leaders that possess superior information can build their reputation and avoid investments uncertainty.
Among similar peers	*Wu et al., (2020)*	Firms provided with information on decisions made by their similar increase the effectiveness of environmental policies in situation of firms heterogeneity.

Authors' own elaboration from the literature

Relying on these studies, next sections will empirically examine through statistical and econometric analysis whether peers' behaviour affects firms in the adoption of pro-environmental decisions.

2.3. Research Methodology

The empirical investigation has been conducted through the elaboration of a questionnaire on Italian manufacturing SMEs during 2019. The aim is to collect information on the state-of-art of CE transition at the firm level, in Italy. Particular interest is addressed to the role of innovation and the level of implementation of eco-innovative practices linked to CE. In accordance, SMEs represent a large part of Italian business, yet their involvement in the CE remains limited. The main barriers identified by the EI literature, on EU firms, are the difficult access to finance, the lack of enforcement and incentives, low technological competences and expertise, the low priority assigned to environmental protection and low perception of benefits, the reluctance toward change and the lack of confidence (Mazzanti et al., 2020). On the other hand, the CE branch of the literature identifies the lack of demand, scarce financial resources and skills, and administrative burdens as the most pressing obstacles hindering CE activities within EU firms (Rizos et al., 2015). However, given the significant participation of SMEs in the Italian economy, their involvement is considered decisive to alter market pathway toward CE transition. Therefore, a deeper understanding of the current engagement of firms and existing bottlenecks and drivers is needed to gather data in support of policy-making, hence directing most conscious efforts toward a systemic CE transition.

2.3.1 The questionnaire

The questionnaire has been developed building on and extending the information of existing official EU sources, such as CIS waves and Eurobarometer surveys. Specifically, it is structured in the following four modules: 1) Firms' characteristics 2) Innovation and Investments 3) Circular Economy 4) Training and Industrial Relations.

The first section is aimed at collecting firms' general information, such as geographical localization, sector classification, data of the respondent person, firms' turnover (2017, 2018), firms' age, export level, number of employees (2017, 2018) and their degree of training. The second section measures, on the one hand, innovation activity, distinguishing between process and product and their level of radicalness, depending on whether the EI is new to the firm or to the market. On the other hand, it investigates firms' investment capacity in R&D, R&D devoted at reducing the environmental impacts of production, and patents' adoption. The third part of the questionnaire is specifically focused on CE and CI adoption. The types of CI included are innovations focused on (a) minimizing the use of water within productive process (b) minimizing materials' usage (c) using renewable energy (d) minimizing energy use (d) minimizing waste use, reuse and selling to other companies (e) re-designing products to reduce the use of materials and enhancing their recyclability (f) reducing greenhouse gases emissions. This section also scrutinizes potential drivers for innovation adoption, making reference to market *vs*. non-market instruments. Finally, the last section examines the importance of green high performance practices, such as organisational training and reskilling activities aimed at coping with the transition to CE, and the role of industrial relations in the adoption of CIs.

Questions about CI adoption

CIs implementation was measured by considering the following question: *"Has the firm introduced innovations aimed at achieving the following CE objectives, in the biennium 2017-2018?"*. A list of CE-oriented innovations was subsequently provided and respondent firms had to choose *"Yes"* in case of adoption and *"No"* otherwise. For the scope of the analysis, a limited set of CIs was selected in correspondence with peers-related questions, specifically: *reducing waste per output produced*; *reusing waste within its own production process, and delivering waste to other companies to be reused in their production process*. This has allowed to investigate the relation between CI adoption and the peer-effect, that otherwise would not have been possible considering the full array of innovations provided by the questionnaire. Although limited to the waste management sphere, selected CIs are not only concerned with incremental changes supporting waste prevention, reuse, and recycling. But they also convey radical modifications, by supporting the creation of firms' networks characterized by integrated productive systems based on the continuous exchange of materials. The chosen CIs are, indeed, examples of product, process, and organisational EIs.

Questions about peer effect

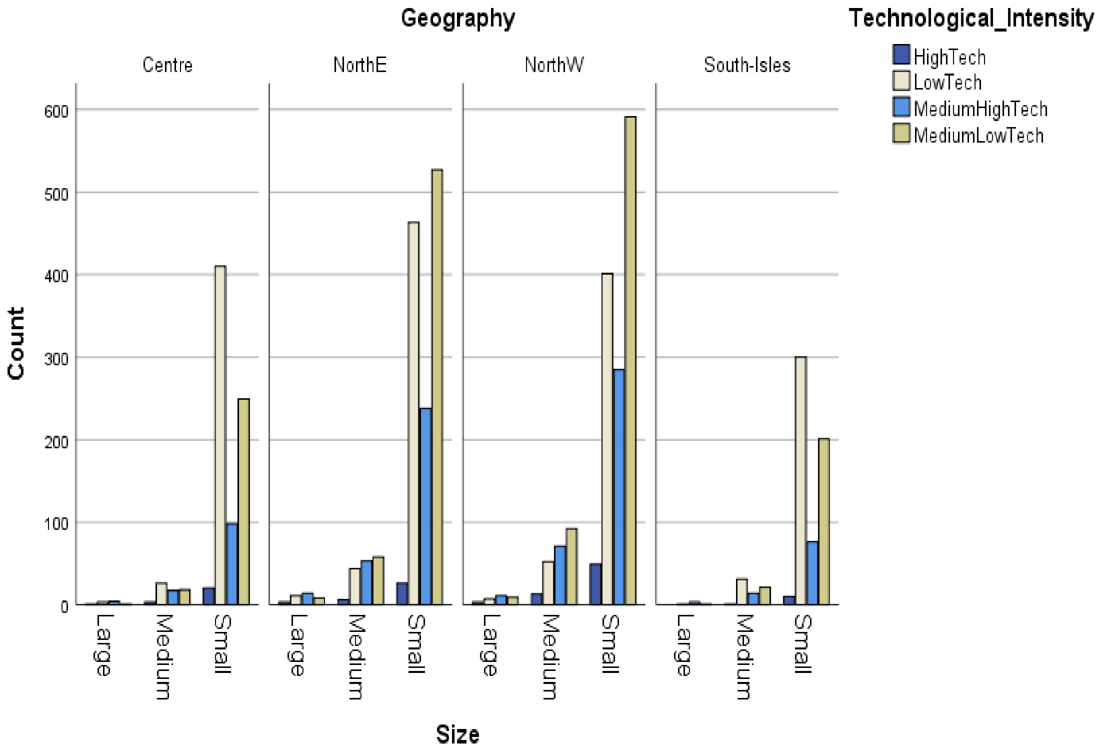
The peer-effect has been measured by resorting to the following questions: 1) "*Do you think that your peers have increased their investments in innovations aimed at reducing waste per output produced*, and/or *at reusing waste within firm's productive process*, and/or *at delivering waste to other companies in the biennium 2017-2018?*. Respondents had therefore to express their knowledge of peers' behaviours, especially on peers' investments in waste-related innovations, considered in this study as a proxy for CIs. To note that, "peer" is the indicator of companies competing in the same market and with similar characteristics. The scope is understanding whether firms that reported introducing at least one CIs think their peers have increased investments directed toward that same type of innovation. As a consequence, whether peers' behaviour affects firms in the adoption of CIs.

2.3.2 Survey presentation

The survey has been organized on Italian manufacturing firms, with at least ten employees, in 2019 by the survey company Izi s.p.a. Data have been gathered through a Computer Assisted Web Interview (CAWI), by providing firms with a questionnaire. The period of time covered is the biennium 2017-2018. The objective was collecting data for at least 4500 firms, which has been overcome since the final sample counts 4565 respondent companies.

The sample has been subsequently stratified by geographical localization (macro area, Istat), sector (technological intensity, Eurostat), and dimension (10-49 employees; 50-249 employees; >250 employees). **Fig. 2.1** shows that respondent firms are mainly situated in North Western Italian regions, followed by North Eastern, Central and Southern regions (including Sicily and Sardinia). Furthermore, prevail firms belonging to low and medium low technology sectors and firms of small dimensions. **Table 2.2** reports the descriptive statistics of the main variables (for further statistics please refer to **Appendix A**, **Table A1**)

Fig.2.1 Firms categorization by geographical localization, size, and technological intensity



Author's own elaboration using SPSS software

2.2 Descriptive statistics of the sample

Variable	Description	Mean	Std. dev.	Min	Max
AGE	Firm age	31.50687	21.33682	1	222
SIZE	Firm dimension	27.0119	31.9084	7	250
GEO	Firm geographical localization	2.344322	1.139878	1	4
TECH	Technological intensity of the firm sector	1.866071	0.821434	1	4
REGTURN	% distribution of firm turnover at regional level	56.77022	37.86981	0	100
NATTURN	% distribution of firm turnover at national level	41.26207	31.6114	0	100
EUTURN	% distribution of firm turnover at EU level	18.28718	21.48639	0	100

37% of Italian SMEs declared having introduced product innovation between 2017-2018, and 40% have implemented process innovation in the same period. Concerning specific EI typologies, 19% of firms adopted innovation to reduce waste, 12% to reuse waste within their production process, and 17% to deliver waste to other firms. In addition, respondent firms reported that reducing waste has mainly concerned process and organisational EIs in order to increase the effectiveness of resource use. On the other hand, reusing waste has mainly involved changes in firms' manufacturing processes that guarantee the circularity of materials. Finally, delivering waste to other firms implies major process and organisational changes, especially due to the creation of firms' networks.

2.3.3. Peer effect and CE-oriented innovations: Descriptive statistics analysis

The empirical analysis is specifically aimed at investigating whether is there any relation between the increase in CIs investments by peers and the introduction of CE-oriented innovations by respondent firms. The goal is to understand whether firms imitate their peers in the adoption of innovations for the CE. In this view, it will be carried out first a descriptive statistic analysis, and building on the obtained results an econometric analysis will be conducted in the next section.

Table 2.3 Cross tabulation between Peer-effect variable and firms introducing CI

		How many Circular Innovation typologies has the firm introduced, in the biennium 2017-2018?					**% Firms introducing at least one CI thinking that peers have increased/decreased their investments**
		0	1	2	3	Total	
Do you think that your peers have increased their investments in Circular Innovation?	Yes	1920	522	334	127	2903	**71,10%**
	No	1262	232	121	47	1662	**28,90%**
	Total	3182	754	455	174	4565	

For the research purpose, two main variables of interest were created to conduct the descriptive statistic analysis. On the one hand, the CE-related innovation variable examines innovation adoption in terms of intensity. It indeed considers overall CIs (namely, waste reduction, waste reuse, and waste delivery) and the number of innovations' typologies introduced per single firm. **Table 2.3** reports 3.182 firms having introduced 0 CIs, 754 firms having introduced one out of three CI typologies, 455 firms two, and 174 firms all three CIs types, between 2017-2018. On the other hand, the peer-effect variable was coded dichotomously in the database to assume the value of 1 if the firm thinks its peers having increased investments in CIs, between 2017-2018, and 0, otherwise. Totally, 2.903 firms have reported an increase in peers' investments, and 1.662 a decrease.

Subsequently, the number of non-innovators was excluded from both CE-related innovations and peer-effect variables. Then, the peer-effect variable assuming value of 0 was divided by the total number of innovative firms. This indicates , how many firms have innovated while thinking their peers having decreased their investments in CIs. Secondly the peer-effect variable assuming value of 1 was divided by the number of innovative firms. This calculates, on the total of innovators, how many introduced CIs while thinking that their peers have increased their investments in the same CI typologies.

The first noteworthy results show that the strong majority (71%) of those who have introduced at least one typology of CE-related innovation considers their peers having increased their investments in the same types of innovation.

The same operation was conducted considering each CI separately. In this case, the innovation variable assumed value 1 when firms introduced the innovation (for waste reduction, waste reuse, and waste delivery to other firms), and 0 otherwise. **Tables 2.4-2.6** confirm that most innovators believe that their peers have increased investments in the same type of CI.

Table 2.4 Cross tabulation between Peer-effect variable and firms innovation to reduce waste per output produced

		Has the firm introduced innovations aimed at reducing waste per output produced, in the biennium 2017-2018?			**%Firms introducing at least one CI thinking that peers have increased/decreased their investments**
		Yes	No	Total	
Do you think that your peers have increased their investments in Circular Innovations?	Yes	643	2260	2903	**73,40%**
	No	233	1429	1662	**26,60%**
	Total	876	3689	4565	

Table 2.5 Cross tabulation between Peer-effect variable and firms innovation to reuse waste within firm's production process

		Has the firm introduced innovations aimed at reusing waste within own production process, in the biennium 2017-2018?			%Firms introducing at least one CI thinking that peers have increased/decreased their investments
		Yes	No	Total	
Do you think that your peers have increased their investments in Circular Innovations?	Yes	381	2522	2903	**69,70%**
	No	166	1496	1662	**30,30%**
	Total	547	4018	4565	

Table 2.6 Cross tabulation between Peer-effect variable and firms innovation to deliver waste to other firms that use it as input in their production process

		Has the firm introduced innovations aimed at delivering waste to other firms that use it as input in their production process, in the biennium 2017-2018?			%Firms introducing at least one CI thinking that peers have increased/decreased their investments
		Yes	No	Total	
Do you think that your peers have increased their investments in Circular Innovations?	Yes	547	2356	2903	**71,70%**
	No	216	1446	1662	**28,30%**
	Total	763	3802	4565	

Further analysis to determine whether any relation exists between the three CIs and the peer effect variables has been conducted through the Phi correlation coefficient using SPSS software support. The phi-coefficient is a variation of Pearson's correlation when the two values of each variable are 0 and 1 respectively. The results (see **Appendix A, Tables A.2-A.4** for further details) suggest that despite the small size effect indicated by the value of the phi-coefficient, a positive and strongly significant association exists between having introduced each CIs typology and believing in an increase of peer investments in the same innovation types.

It emerges that according to descriptive statistic results the peer-effect and CIs variables are positively related. Notwithstanding, in order to obtain stronger evidence on the effect of peer behaviours in driving CIs, an econometric analysis is required.

2.3.4. Peer effect and CE-oriented innovations: Econometric Analysis

This study is aimed to determine the impact of peers' behaviour on the adoption of CI using probit regression. The probit model is a statistical probability model with a binary dependent variable. Indeed, given the dichotomous nature of the choice to innovate or not to innovate, y is valued as zero and one. The probit analysis provides results on which determinants increase or decrease the probability of innovating.

Three binary dependent variables will be considered for specific waste-related innovations. For each CI, respondent firms have to decide whether to introduce the innovation related to this field (Y=1) or not introducing it (Y=0). Different factors may influence this decision, and they are indicated with a vector x. Therefore, the analysis deals with an estimation of the probability:

$$p_i = prob[Y_i = 1|x] = F(x,\beta)$$

A normal distribution is assumed. The β parameter indicates the effect of changes in x on the probability. Subsequently, the relationship between explanatory variables and the outcome of probability has been interpreted using the average marginal effect, which considers the partial change in the probability when x increases by one unit, holding the other variables constant. The marginal effect suggests how the explanatory variables shift the probability of being an innovator. The following equation has been used for the empirical analysis:

$$CI_i = \alpha + \beta_1 PEER_i + \beta_2 SIZE_i + \beta_3 AGE_i + \beta_4 RED_i + \beta_5 INDUSTRY4.0_i + \beta_6 TECH_i + \beta_7 COSTWAS_i + \beta_8 POLICY_i + \beta_9 NORTH_i + \beta_{10} CENTRE_i + \beta_{11} SOUTH_i + \varepsilon_i$$

The dependent variables introduced to capture CI, are *WASRED* (Innovation to reduce waste per output produced), *WASREUSE* (Innovation for reusing waste within own productive process), *WASDELIV* (Innovation for the delivery of waste to other companies to be reused in their productive process). *PEER* is the main driver under scrutiny indicating the influence of peers' behaviour for the introduction of innovation. The independent variables intending to capture CI are the following: (i) *SIZE* is a continuous variable indicating firms' dimension accounting for the number of employees in 2017. (ii) *AGE* is a continuous variable expressing the age of respondent firms. (iii) *RED* is a dummy variable with value of 1 if the firm undertakes R&D investments between 2017-2018. (iv) *INDUSTRY4.0* is a dummy variable taking value of 1 if the firm introduced technological innovations by exploiting the opportunities of the Industry 4.0 program in 2017-2018; (v) *TECH* a categorical variable measuring in ascending order the technological intensity of the sector which the firm belongs to i.e. low technology, medium-low technology, medium-high technology, high-technology. (vi) *COSTWAS* refers to firms' perception of the increase in future waste disposal costs for the biennium 2019-2020. It captures the impact of market-oriented factors as a pressure instrument in firms' decisions for introducing CIs. Firms have to respond to the following question: *How much do you think the cost of waste disposal relevant to your business will increase in the 2019-2020 biennium?*. Respondents could specify the percentage of increase (from 0%-100%) or opt for "*I do not know*". Data have been collected in a categorical variable accounting for different steps of increase. Observations deriving from the option "*I do not know*" have been considered as 0, since not being aware of increased disposal costs has been considered as having no effect on the decision to innovate due to market pressures[4]. *POLICY* is a continuous variable indicating the total management costs of mixed municipal waste (€/hab. per year) in 2017. Data have been collected using a database of ISPRA the Italian Institute for Environmental Protection and Research. The variable has been interpreted as a policy stringency indicator of the municipality in which firms operate. *NORTH*, *SOUTH* and *CENTRE* are three dummy variables that take value of 1 depending on whether the firm is located in regions of Northern, Central or Southern Italy. All variables influencing firms decision to innovate included in the model are summarised in **Table 2.7** with summary statistics.

Table 2.7 Descriptive statistics

Variable	Description	Mean	Std. dev.	Min	Max
PEER	Firms perception of increase/decrease of peers investments on waste-related innovations (2017-2018)	0.636	0.481	0	1
SIZE	Firm dimension (2017)	2.733	3.269	7	250
AGE	Firm age	3.212	21.681	1	222
RED	Investments in R&D (2017-2018)	0.313	0.463	0	1
INDUSTRY4.0	Introduction of technological innovations using the Program Industry 4.0 (2017-2018)	0.208	0.406	0	1
TECH	Technological intensity of the sector	1.898	0.827	1	4
ATECO	ATECO code of the sector	2.233	6.600	10	33
COSTWAS	Firms' expectation of the increasing of future cost of waste disposing of primary importance to their activity (2019-2020)	0.276	0.588	0	4
POLICY	Total management costs of mixed municipal waste (€/hab. per year) (2017)	4.595	2.573	2.63	213.18

[4] To correct the potential inaccuracy of this information we have lead a robustness check with costwas≠0 and we obtain estimates qualitatively consistent with the original model, available under request.

NORTH	Regions of Northern Italy	0.707	0.455	0	1
CENTRE	Regions of Central Italy	0.178	0.382	0	1
SOUTH	Regions of Southern Italy	0.114	0.318	0	1

2.4 Empirical Results

The main econometric results are reported in **Table 2.8**. Each column indicates the average marginal effect of Probit estimates (Refer to **Table A.5** in Appendix for Probit estimates results) for all firms of the sample regarding the introduction of the three typologies of CIs. It clearly emerges that PEER is positively and significatively correlated with the adoption of all CIs. Indeed, considering peers having raised investments for the three typologies of innovations in question corresponds to higher probability of introducing innovation for waste reduction by 6%, for waste reuse by 2,6%, and for waste delivery by 5,6%. The results comply with the findings in Wu et al., (2020) which found that information on decisions taken by similar firms increases the probability of adopting an innovation.

Table 2.8 Determinants of CI: marginal effect

Estimation Method:	Probit	Probit	Probit
Dependent Variable:	Innovation to reduce waste per output produced	Innovation for reusing waste within own productive process	Innovation for delivery waste to other companies to be reused in their productive process
PEER	**0.0639*****	**0.0259****	**0.0565*****
	(0.0140)	(0.0118)	(0.0137)
SIZE	-0.0000607	0.0000461	-0.00000681
	(0.000195)	(0.000163)	(0.000200)
AGE	0.000383	0.000688***	0.000564*
	(0.000295)	(0.000253)	(0.000291)
RED	0.147***	0.0859***	0.0421***
	(0.0139)	(0.0121)	(0.0144)
INDUSTRY4.0	0.0589***	0.0373***	0.0574***
	(0.0156)	(0.0131)	(0.0155)
TECH_ML	0.000999	0.0225*	0.00602
	(0.0157)	(0.0135)	(0.0152)
TECH_MH	-0.0344*	-0.0237	-0.0268
	(0.0183)	(0.0146)	(0.0177)
TECH_H	-0.0737**	-0.0679***	-0.0585*

	(0.0312)	(0.0215)	(0.0312)
COSTWAS	0.0564***	0.0285***	0.0415***
	(0.01000)	(0.00837)	(0.00987)
POLICY	0.000604**	0.000510**	0.0000157
	(0.000272)	(0.000228)	(0.000269)
Regional dummy	Yes	Yes	Yes
N. Obs.	3270	3270	3270

Notes: Reported are average marginal effects. Standard errors in parentheses. *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Regional dummies are dummies per Northern, Central and Southern Italian Regions.

Another factor explaining the adoption of CI is investment in R&D (RED), the variable is indeed positive and highly significative for all CIs' typologies. Accordingly, having invested in R&D between 2017-2018 increases on average the probability of adopting innovation for waste reduction by 14,7%, for by-product reuse by 8% and for waste exchange to other production processes by 4%. This indicates that CIs requires the availability of knowledge capital as a condition to be implemented, indeed as identified in De Jesus and Mendonça (2018), an adequate support of R&D activities positively increases the knowledge base necessary for CE. Notwithstanding, still the positive role of R&D investments has not been completely confirmed for EIs in the realm of CE. Indeed, these findings are in contrast with those presented in Cainelli et al., (2020), in which R&D results negatively affect EI-related to RE. This demonstrates the need to provide more robust results on the role of R&D among CI drivers. On the other side, there is a large consensus in the EI literature, among the others in Horbach (2008) and in Horbach et al., (2012), that R&D investments have been recognized as having a positive role on firms' technological capabilities, which plays a crucial role in the realization of EI.

Table 2.8 shows that the introduction of CI aimed at both waste reduction and reuse receives the positive, albeit weak, effect of stringent policies. Indeed, operating in a municipality with higher waste management costs increases on average the probability of introducing innovation for waste reduction by 0,06% and for waste reuse by 0,05%. Differently, the regulation does not seem to affect the adoption of innovation in favour of by- products exchange. On the one hand, these findings are in line with the literature on EI, recognizing a positive effect of environmental policy in determining the adoption of eco-innovative solutions. Indeed, since companies are not motivated to adopt EI, as they would enhance the quality of the environment at their cost while producing societal benefits, stricter environmental policies and regulations have been proved to be crucial to increasing firms' incentive to adopt EI in order to decrease compliance costs. (Rennings, 2000). As pointed out in Barbieri et al. (2016) p. 607 «*by changing the relative prices of production factors or by setting new (environmental) standards, existing as well as forthcoming policies induce (environmental) innovations in each of the phases of the Schumpeterian innovation process, from invention to adoption and diffusion*». On the other hand, such results comply with a branch of literature more strictly connected to EI and CE. For example, in De Jesus and Mendonça (2018), the authors identify a positive link between eco-innovative practices leading to CE and soft drivers, such as regulatory and institutional. Also in Cainelli at al. (2020) the positive effect of environmental policy has been verified for the introduction of innovation encouraging recycling, waste reduction and the decrease in resources' use. Further to this, the fact that stringent policies are not sufficient to justify firms' exchanges of waste, demonstrates the existence of heterogeneity between different typologies of CI introduction. This specific CI may be more costly in terms of both economics and effort. Especially, with regard to the latter, the supply of own waste to other companies asks for the presence of networks and a well-established structure that regulates the matching of waste supply and demand, for which more targeted policy interventions are needed. It is worth noting, however, that the variable POLICY focuses on the management cost of mixed waste, which constitutes only a part of the overall waste typology generated by companies, mostly dealing with special waste. For this reason, in order to control for this potential limit, the analysis also takes into consideration the perceived increase in the cost of managing the waste of first importance for responding companies. This allows detecting, whether the expected change of relative prices for their specific waste management, which may occur with the imposition of more stringent environmental standards, significantly affects firms through innovation reactions. This effect is confirmed as demonstrated by the variable COSTWAS, indicating that a perceived increase of the relative prices induces on average innovation for waste reduction by 5,6%, innovation for waste reuse by 3%, and innovation for waste exchange by 4%.

An additional positive effect generated by the policy, this time activated by a subsidy, is suggested by the positive and significant relation among CE-innovation adoption and the exploitation of the Italian program of *Industry 4.0*. This plan is aimed at providing incentives to firms for the introduction of new technological regimes. Industry 4.0 covers all aspects of the lifecycle of companies, offering support for investment, digitization of production processes, enhancing worker productivity, and training appropriate skills (e.g. through hyper and super depreciation plans, the tax credit for R&D, incentives for investments in innovative start-ups and SMEs). **Table 2.8** shows that using the incentives provided by the plan of Industry 4.0 increases on average the probability of adoption respectively of innovation to reduce waste per output produced by 6%, of innovation for reusing waste within its own productive process by 4%, and of innovation for delivering waste to other companies to be reused in their productive process by 6%. Following this, interestingly, TECH indicates a negative relation with the technological intensity of the sector in which firms operate and the introduction of CIs. In accordance, belonging to high technology sectors on average decreases the probability of introducing innovations for waste reduction by 7%, innovation for waste reuse by 6%, and innovation for the delivery of waste to other companies by 6% compared to operating in low-technology sectors. In addition, belonging to medium-high technology sectors on average decreases the probability of introducing innovations for waste reduction by 3% compared to operating in low-technology sectors. Further analysis is therefore required to better investigate this relation. In first instance, it is necessary to understand whether the same effect persists in relation to the introduction of innovation in general within the same sample of firms. This will allow verifying whether the negative relationship between the sector's technology and innovative capacity relates specifically to innovations linked to the CE or to all innovations' typologies. In **Table 2.9** the dependent variables of CI have been therefore substituted with two dummy variables indicating the introduction or not of standard product and process innovations (i.e. *Has the firm introduced product innovations in the biennium 2017-2018*?; *Has the firm introduced product innovations in the biennium 2017-2018*?).

Table 2.9 Determinants of the introduction of product and process innovations

Estimation Method:	Probit	Probit
Dependent variable	Introduction of product innovation	Introduction of process innovation
PEER	0.0486***	0.0633***
	-0.0149	-0.0158
SIZE	-0.00000966	0.000163
	-0.000217	-0.00024
AGE	0.000482	-0.000262
	-0.000338	-0.00035
RED	0.406***	0.320***
	-0.0108	-0.0143
IND40	0.0670***	0.240***

	-0.0183	-0.0183
1.TECH	0	0
	(.)	(.)
2.TECH	-0.0445***	0.0471***
	-0.017	-0.0177
3.TECH	0.0699***	0.0177
	-0.0214	-0.0219
4.TECH	0.0837*	0.0227
	-0.0442	-0.0449
COSTWAS	0.0176	0.0490***
	-0.0124	-0.0128
POLICY	0.000389	0.0000317
	-0.000306	-0.000325
Regional dummy	Yes	Yes
N. Obs.	3270	3270

Notes: Reported are Probit Model estimations. Standard errors in parentheses . *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Regional dummies are dummies per Northern, Central and Southern Italian Regions.

Table 2.9 shows that, on average, operating in higher technology sectors generally increases the probability of introducing both production and process innovation between 2017-2018. These results confirm that the negative relation between technological intensity and innovation adoption is specifically related to CIs, and therefore that CIs are mainly introduced by low-technological firms. This may depend on the specific activities carried out by these firms which may work in fields directly related to CE, or in which introducing CI requires less effort, perhaps for the nature of the waste to manage. In order to check for this, the study considers a further categorization of sectors, which includes the ATECO codes.

Table 2.10 Robustness check with ATECO codes

Estimation Method:	Probit	Probit	Probit
Dependent variable:	Innovation to reduce waste per output produced	Innovation for reusing waste within own productive process	Innovation for delivery waste to other companies to be reused in their productive process
SIZE	-0.000251	-0.000105	-0.0000548
	(0.000801)	(0.000905)	(0.000850)
AGE	0.00180	0.00399***	0.00187
	(0.00121)	(0.00139)	(0.00125)
RED	0.591***	0.453***	0.166***

	(0.0585)	(0.0652)	(0.0606)
INDUSTRY4.0	0.228***	0.182***	0.224***
	(0.0639)	(0.0703)	(0.0654)
PEER	0.259***	0.136**	0.236***
	(0.0571)	(0.0634)	(0.0572)
COSTWAS	0.224***	0.135***	0.156***
	(0.0414)	(0.0456)	(0.0421)
POLICY	0.00235**	0.00273**	0.0000276
	(0.00112)	(0.00124)	(0.00113)
NORTH	0.0332	-0.0675	-0.0603
	(0.0966)	(0.107)	(0.0940)
CENTRE	-0.0477	-0.286**	0.00640
	(0.107)	(0.121)	(0.104)
SOUTH	0	0	0
	(.)	(.)	(.)
Constant	-1.486***	-1.769***	-1.200***
	(0.142)	(0.161)	(0.136)
Sectorial dummy	Yes	Yes	Yes
N. Obs.	3265	3265	3265

Notes: Reported are Probit Model estimations. Standard errors in parentheses . *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Sectorial dummies are dummies per each ATECO code

Table 2.10 shows that by introducing sectoral dummies corresponding to firms' ATECO codes, the peer effect is positively confirmed per each CE innovation.

Table 2.11 Robustness check in ATECO subsamples: Innovation to reduce waste per output produced

Sector:	Food Industry	Textile Industry	Clothing manufacture	Manufacture of leather goods	Wood industry excluding furniture	Paper Industry	Press	Manufacture of chemicals	Manufacture of rubber articles	Manufacture of other mineral products
Sectors' technological intensity:	LT	LT	LT	LT	LT	LT	LT	MHT	MLT	MLT
ATECO code:	10	13	14	15	16	17	18	20	22	23
Innovation to reduce waste per output produced	0.125	0.620**	0.594*	0.0893	0.449	0.195	1.046**	0.695	0.331	0.0877
	(0.179)	(0.302)	(0.310)	(0.308)	(0.318)	(0.413)	(0.457)	(0.463)	(0.212)	(0.354)
N.obs	298	137	142	127	112	65	91	70	208	113

Sector:	Metallurgy	Manufacture of metal products	Manufacture of pc and electronic products	Manufacture of electrical equipment	Manufacture of machinery and equipment	Manufacture of motor vehicles	Manufacture of other transport equipment	Manifacture of furniture	Other manifacturing industries	Machine repair, maintenance and installation
Sectors' technological intensity:	MLT	MLT	HT	MHT	MHT	MHT	MHT	LT	LT	MLT
ATECO code:	24	25	26	27	28	29	30	31	32	33

Innovation to reduce waste per output produced	0.338	0.0935	0.260	0.299	0.521***	-0.730	-0.124	-0.233	0.543	0.268
	(0.648)	(0.114)	(0.376)	(0.298)	(0.185)	(0.499)	(.)	(0.361)	(0.396)	(0.285)
N.obs	46	806	93	143	358	38	21	115	70	135

Notes: Reported Probit Model. Standard errors in parentheses . *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Low Technology sector(LT); Medium-Low Technology sector (MLT); Medium-High Technology sector (MHT); High Technology sector (HT). ATECO 11, 12, 19,21, 30 not reported due to insufficient observations.

Table 2.12 Robustness check in ATECO subsamples: Innovation to reuse waste within own productive process

Sector:	Food Industry	Textile Industry	Clothing manufacture	Manufacture of leather goods	Wood industry excluding furniture	Paper Industry	Press	Manufacture of chemicals	Manufacture of rubber articles	Manufacture of other mineral products
Sectors' technological intensity:	LT	LT	LT	LT	LT	LT	LT	MHT	MLT	MLT
ATECO code:	10	13	14	15	16	17	18	20	22	23
Innovation for reusing waste within own productive process	0.116	0.121	0.558	0.153	-0.127	0.153	2.545***	0.734	0.203	0.361
	(0.212)	(0.336)	(0.581)	(0.363)	(0.334)	(0.447)	(0.669)	(0.602)	(0.206)	(0.372)
N.Obs	298	130	113	109	105	65	84	70	208	113

Sector:	Metallurgy	Manufacture of metal products	Manufacture of pc and electronic products	Manufacture of electrical equipment	Manufacture of machinery and equipment	Manufacture of motor vehicles	Manifacture of furniture	Other manifacturing industries	Machine repair, maintenance and installation
Sectors' technological intensity:	MLT	MLT	HT	MHT	MHT	MHT	LT	LT	MLT
ATECO code:	24	25	26	27	28	29	31	32	33
Innovation for reusing waste within own productive process	-0.108	-0.103	0.654	-0.148	0.191	-875.7	-0.0498	1.315**	0.439
	(0.563)	(0.125)	(0.514)	(0.300)	(0.207)	(.)	(0.423)	(0.536)	(0.424)
N.Obs	49	806	84	143	358	10	115	70	103

Notes: Reported Probit Model. Standard errors in parentheses . *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Low Technology sector(LT); Medium-Low Technology sector (MLT); Medium-High Technology sector (MHT); High Technology sector (HT). ATECO 11, 12, 19,21, 30 not reported due to insufficient observations.

Table 2.13 Robustness check in ATECO subsamples: Innovation for delivery waste to other companies

Sector:	Food Industry	Beverage Industry	Textile Industry	Clothing manufacture	Manufacture of leather goods	Wood industry excluding furniture	Paper Industry	Press	Manufacture of chemicals	Manufacture of rubber articles
Sectors' technological intensity:	LT	LT	LT	LT	LT	LT	LT	LT	MHT	MLT
ATECO code:	10	11	13	14	15	16	17	18	20	22
Innovation for delivery waste to other companies to be reused in	0.568***	0	0.0860	0.174	0.192	0.135	0.310	1.527***	0.00679	0.329
	(0.197)	(.)	(0.294)	(0.302)	(0.348)	(0.280)	(0.401)	(0.480)	(0.495)	(0.208)

their productive process										
N.obs.	298	10	130	142	127	126	65	84	66	208
Sector:	Manufacture of other mineral products	Metallurgy	Manufacture of metal products	Manufacture of pc and electronic products	Manufacture of electrical equipment	Manufacture of machinery and equipment	Manufacture of motor vehicles	Manifacture of furniture	Other manifacturing industries	Machine repair, maintenance and installation
Sectors' technological intensity:	MLT	MLT	MLT	HT	MHT	MHT	MHT	LT	LT	MLT
ATECO code:	23	24	25	26	27	28	29	31	32	33
Innovation for delivery waste to other companies to be reused in their productive process	1.000***	1.208**	0.169	0.361	0.289	0.150	-3.388***	-0.339	0.251	0.131
	(0.312)	(0.610)	(0.113)	(0.402)	(0.322)	(0.169)	-1.053	(0.300)	(0.367)	(0.335)
N.obs.	113	49	806	84	143	358	38	115	77	135

Notes: Reported Probit Model. Standard errors in parentheses . *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Low Technology sector(LT); Medium-Low Technology sector (MLT); Medium-High Technology sector (MHT); High Technology sector (HT). ATECO 12, 19,21, 30 not reported due to insufficient observations.

Furthermore, Tables **2.11-2.13** check the peer effect within the different ATECO subsamples in order to verify in which specific sectors the introduction of innovation follows peers' imitation logic. The results demonstrate that: for waste reduction, the peer effect is positively and significantly related to innovation introduction in the textile industry, clothing manufacture, press, and manufacture of machinery and equipment; for waste reuse, the peer effect is positively and significantly related to innovation introduction in the press and other manufacturing industries, and for waste exchange, the peer effect is significantly and positively related to innovation introduction in the food industry, press, manufacture of mineral products, metallurgy, and negatively and significantly related to innovation introduction in the manufacture of motor vehicles. To note that, the majority of the aforementioned activities correspond to low technology and medium-low technology sectors, confirming previous results (refer to **Table 2.8**). More specifically, peers' behaviours seem to be particularly correlated with CI in the press sector. Although a targeted analysis is required in order to establish the reasons for this relation, the nature of paper which is renewable recyclable, biodegradable, and compostable likely facilitate waste-related innovations adoption. For example, cellulose pulp can be immediately reused for new production cycles. This creates advantages for waste paper and its industrial by products, in terms of inflow of secondary raw material used both by paper manufacturers for multiple processes or to be sold to other industries, indeed paper sludge is nutritious for plants, hence crop productivity. In turn, this creates further positive impacts on the reduction of waste amount production. On the other hand, CIs related to waste reduction appear positively correlated withpeers' actions in the textile industry and clothing manufacturing. In this concern, the EU recognises the high environmental impact of the textile and clothing industry in terms of raw material use and waste production. Many actions have been taken to transform this sector in compliance with CE objectives, the most recent being the EU Strategy for Sustainable Textiles. The impulse of European policies is therefore providing the push for the diffusion of new policies also at the national level, aimed at modifying traditional production and consumption systems. For example, the introduction of the obligation to collect textile waste separately, in Italy, which came into force on 1 January 2022, as provided for in Legislative Decree 116/2020, while at EU level, separate collection of this type of waste will become mandatory by 2025. In this context, therefore, it is likely that companies are beginning a process of progressive adaptation that requires, among others, the adoption of new supporting innovations, which may be guided also by examples of good practice among their peers. Finally, peer behaviours result positively related with the introduction of innovation aimed at food waste exchange. Food waste represents indeed another critical channel for the increase in the amount of waste generated, which has therefore required the EU to intervene with specific measures. Specifically, Directive 851/2018/EU defines targets for the prevention and reduction of food waste by 2030. In this area, probably stricter regulations and the increase of the social norm in this direction are positively stimulating the exchange of food waste in order to allocate it to other sectors from a bio-economy perspective.

2.5. Conclusions

The establishment of circular paths requires social and economic changes. The role of radical and incremental EI is decisive for this transition to take place. The purpose of this chapter is to shed light on how innovation can be promoted at the firm level, with positive effects on the capacity of companies to adapt to the CE requirements. More studies are needed to understand how to theoretically intertwine the concept of CE with that of EI. This chapter has assumed that understanding the factors involved in firms' decisions to innovate could eventually clarify this evolving research area.

It has been empirically analysed whether the context in which firms operate is capable of triggering innovative processes. Starting from the concepts of social norm and peer comparison, analysed by behavioural economics on consumers, and going through a recent strand of literature analysing the effect of peers on firms' decisions, this chapter examined whether the choice to introduce CI has some relation with peers' behaviour. Specifically, the study investigated whether believing that peers are increasing their investment in certain innovations has a positive influence on firms, which will then be more likely to innovate. The results show the relevance of the peer effect and its positive correlation with CI adoption. CI has been considered, in this chapter, as an innovation aimed at reducing waste generated per output produced, reusing waste within the company's production process, and delivering it to other companies that use it as an input in their production process. Consequently, considering peers to have increased investment in the three typologies of innovation in question corresponds to an increase in the likelihood of introducing innovative practices of the same type. We consider these results relevant both for the contribution they make to the literature on the subject, which is still little explored, and at the policy level. Indeed, understanding what are the enabling factors of CE is a fundamental requirement for the design of policies able to effectively stimulate firms' behaviour. If the social context in which firms operate plays a role in their decision-making, it should be exploited to support and complement traditional regulatory market instruments. For example, firms can be stimulated with information on the performance of their peers regarding the adoption of CI. However, the efficacy of this instrument depends to a large extent on how information on social norms is articulated. Indeed, providing firms with data on investments on CI or adoption of CI by peers may cause rebound effects, hence dis-adoption, in cases in which firms that received the information recorded higher performance. This can be avoided through the provision of dynamic social norm (e.g. "*More firms are investing in CI*"), which however can only be applied in cases of increasing adoption trends.

This study is not without its limitations. First, the gathering of data through the administration of a questionnaire may incur in misunderstanding of questions. Indeed, despite the definitions of the key terms such as "innovation" have been provided, we are not aware of the level of knowledge of respondents on the topic. Furthermore, in this regard, although an attempt was made to limit the filling in of the questionnaire to employees employed in top management positions of the firm, it cannot be excluded that some of them did not have complete knowledge or involvement in the decision-making processes of the firm and were therefore able to provide comprehensive answers. Second, a simultaneity bias may exist between thinking that peers invested in CI and the introduction of CI in the own firm. For this reason, we must be cautious in affirming a causality relation between the PEER variable and CIs adoption. Further research will exploit data from the second wave of the survey conducted by CERCIS in 2021. This will allow to build a panel dataset in which 2.305 Italian manufacturing firms are observed in two time periods, in order to test and possibly strengthen the results obtained in the cross-sectional analysis.

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Appendix A

Table A.1 Descriptive statistics of the sample

AGE					SIZE				
Percentiles		**Smallest**			**Percentiles**		**Smallest**		
1%	3	1			1%	8	7		
5%	6	1			5%	9	7		
10%	8	1	**Obs**	4,368	10%	10	7	**Obs**	4,368
25%	16	2	**Sum of wgt.**	4,368	25%	12	7	**Sum of wgt.**	4,368
50%	29		**Mean**	31.5069	50%	15		**Mean**	27.0119
		Largest	**Std. dev.**	21.3368			**Largest**	**Std. dev.**	31.9084
75%	42	187			75%	28	245		
90%	57	198	**Variance**	455.26	90%	53	249	**Variance**	1018.15
95%	66	200	**Skewness**	1.80016	95%	87	250	**Skewness**	3.62341
99%	110	222	**Kurtosis**	10.4353	99%	191	250	**Kurtosis**	18.4487

GEO					TECH				
Percentiles		**Smallest**			**Percentiles**		**Smallest**		
1%	1	1			1%	1	1		
5%	1	1			5%	1	1		
10%	1	1	**Obs**	4,368	10%	1	1	**Obs**	4,368
25%	1	1	**Sum of wgt.**	4,368	25%	1	1	**Sum of wgt.**	4,368
50%	3		**Mean**	2.34432	50%	2		**Mean**	1.86607
		Largest	**Std. dev.**	1.13988			**Largest**	**Std. dev.**	0.82143
75%	3	4			75%	2	4		
90%	4	4	**Variance**	1.29932	90%	3	4	**Variance**	0.67475
95%	4	4	**Skewness**	0.05296	95%	3	4	**Skewness**	0.56913
99%	4	4	**Kurtosis**	1.54373	99%	4	4	**Kurtosis**	2.50546

REGTURN					NATTURN				
Percentiles		**Smallest**			**Percentiles**		**Smallest**		
1%	0	0			1%	0	0		
5%	0	0			5%	1	0		
10%	3	0	**Obs**	3,412	10%	5	0	**Obs**	3,335
25%	18	0	**Sum of wgt.**	3,412	25%	13	0	**Sum of wgt.**	3,335
50%	65		**Mean**	56.7702	50%	35		**Mean**	41.2621
		Largest	**Std. dev.**	37.8698			**Largest**	**Std. dev.**	31.6114
75%	97	100			75%	66	100		
90%	100	100	**Variance**	1434.12	90%	93	100	**Variance**	999.28
95%	100	100	**Skewness**	-0.2331	95%	100	100	**Skewness**	0.47763
99%	100	100	**Kurtosis**	1.44698	99%	100	100	**Kurtosis**	1.97928

EUTURN

Percentiles		Smallest		
1%	0	0		
5%	0	0		
10%	0	0	**Obs**	2,528
25%	1	0	**Sum of wgt.**	2,528
50%	10		**Mean**	18.2872
		Largest	**Std. dev.**	21.4864
75%	30	100		
90%	50	100	**Variance**	461.665
95%	63	100	**Skewness**	1.47454
99%	91	100	**Kurtosis**	4.8058

Table A.2 Contingency Table: Innovation to reduce waste per output produced

		Has the firm introduced innovations aimed at reducing waste per output produced, in the biennium 2017-2018?			%Firms introducing at least one CI thinking that peers have increased/decreased their investments
		Yes	No	Total	
Do you think that your peers have increased their investments in Circular Innovations?	Yes	643	2260	2903	**73,40%**
	No	233	1429	1662	**26,60%**
	Total	876	3689	4565	

		Value	Approximate Significance
Nominal by Nominal	Phi	,099	,000
	Cramer's V	,099	,000
N of Valid Cases		4565	

Table A.3 Contingency Table: Innovation to reuse waste within own productive process

		Has the firm introduced innovations aimed at <u>reusing waste within own production process</u>, in the biennium 2017-2018?			%Firms introducing at least one CI thinking that peers have increased/decreased their investments
		Yes	No	Total	
Do you think that your peers have increased their investments in Circular Innovations?	Yes	381	2522	2903	**69,70%**
	No	166	1496	1662	**30,30%**
	Total	547	4018	4565	

		Value	Approximate Significance
Nominal by Nominal	Phi	,046	,002
	Cramer's V	,046	,002
N of Valid Cases		4565	

Table A.4 Contingency Table: Innovation to deliver waste to other firms as input for their productive process

		Has the firm introduced innovations aimed at <u>delivering waste to other firms that use it as input in their production process</u>, in the biennium 2017-2018?			%Firms introducing at least one CI thinking that peers have increased/decreased their investments
		Yes	No	Total	
Do you think that your peers have increased their investments in Circular Innovations?	Yes	547	2356	2903	**71,70%**
	No	216	1446	1662	**28,30%**
	Total	763	3802	4565	

		Value	Approximate Significance
Nominal by Nominal	Phi	,075	,000
	Cramer's V	,075	,000
N of Valid Cases		4565	

Table A.5 Determinants of Circular Innovation: Probit Model Estimation

	Innovation to reduce waste per output produced	Innovation for reusing waste within own productive process	Innovation for delivery waste to other companies to be reused in their productive process
PEER	0.259***	0.138**	0.235***
	(0.0570)	(0.0627)	(0.0571)
SIZE	-0.000246	0.000245	-0.0000283
	(0.000790)	(0.000867)	(0.000832)
AGE	0.00155	0.00365***	0.00234*
	(0.00120)	(0.00134)	(0.00121)
RED	0.594***	0.456***	0.175***
	(0.0583)	(0.0647)	(0.0601)
INDUSTRY4.0	0.238***	0.198***	0.239***
	(0.0636)	(0.0695)	(0.0647)
TECH_ML	0.00392	0.113*	0.0242
	(0.0615)	(0.0678)	(0.0613)
TECH_MH	-0.143*	-0.136	-0.115
	(0.0776)	(0.0860)	(0.0776)
TECH_H	-0.335**	-0.483**	-0.273*
	(0.163)	(0.203)	(0.165)
COSTWAS	0.228***	0.151***	0.173***
	(0.0408)	(0.0444)	(0.0412)
POLICY	0.00245**	0.00270**	0.0000651
	(0.00110)	(0.00121)	(0.00112)
Constant	-1.542***	-1.724***	-1.311***
	(0.125)	(0.137)	(0.119)
Regional dummy	Yes	Yes	Yes
N	3270	3270	3270

Notes: Reported Probit model estimations. Standard errors in parentheses . *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Regional dummies are dummies per Northern, Central and Southern Italian Regions.

Table A.6 Robustness check with ATECO codes

	Innovation to reduce waste per output produced	Innovation for reusing waste within own productive process	Innovation for delivery waste to other companies to be reused in their productive process
SIZE	-0.000251	-0.000105	-0.0000548
	(0.000801)	(0.000905)	(0.000850)
AGE	0.00180	0.00399***	0.00187
	(0.00121)	(0.00139)	(0.00125)
RED	0.591***	0.453***	0.166***
	(0.0585)	(0.0652)	(0.0606)
INDUSTRY4.0	0.228***	0.182***	0.224***
	(0.0639)	(0.0703)	(0.0654)
PEER	0.259***	0.136**	0.236***
	(0.0571)	(0.0634)	(0.0572)
ATECO=10	0	0	0
	(.)	(.)	(.)
ATECO=11	0.318	0.158	0.0843
	(0.328)	(0.381)	(0.345)
ATECO=12	0	0	0
	(.)	(.)	(.)
ATECO=13	-0.103	0.0610	-0.178
	(0.156)	(0.178)	(0.160)
ATECO=14	-0.196	-0.174	-0.292*
	(0.161)	(0.196)	(0.163)
ATECO=15	-0.136	0.108	-0.428**
	(0.168)	(0.195)	(0.180)
ATECO=16	-0.124	0.152	0.0853
	(0.159)	(0.178)	(0.153)
ATECO=17	-0.0711	0.308	0.194
	(0.204)	(0.212)	(0.192)
ATECO=18	0.00390	0.0336	-0.268
	(0.176)	(0.204)	(0.186)
ATECO=19	0	0	0
	(.)	(.)	(.)
ATECO=20	-0.0470	0.288	-0.170
	(0.189)	(0.201)	(0.199)
ATECO=21	-0.390	-0.309	-0.215
	(0.413)	(0.501)	(0.416)
ATECO=22	0.128	0.645***	0.176
	(0.132)	(0.142)	(0.130)
ATECO=23	-0.397**	0.113	-0.153
	(0.181)	(0.183)	(0.168)
ATECO=24	-0.334	0.121	0.0270
	(0.240)	(0.237)	(0.217)
ATECO=25	-0.0765	0.0710	-0.0994
	(0.103)	(0.120)	(0.102)

ATECO=26	-0.402**	-0.419*	-0.382**
	(0.189)	(0.237)	(0.192)
ATECO=27	-0.205	0.0599	-0.243
	(0.158)	(0.174)	(0.160)
ATECO=28	-0.260**	-0.164	-0.182
	(0.122)	(0.142)	(0.121)
ATECO=29	0.0791	0.00744	0.141
	(0.246)	(0.275)	(0.245)
ATECO=30	-0.458	-0.713*	-1.030**
	(0.290)	(0.431)	(0.438)
ATECO=31	-0.186	-0.152	0.00575
	(0.167)	(0.201)	(0.164)
ATECO=32	0.0478	0.428**	-0.165
	(0.188)	(0.200)	(0.198)
ATECO=33	0.0309	0.00830	-0.248
	(0.157)	(0.191)	(0.165)
COSTWAS	0.224***	0.135***	0.156***
	(0.0414)	(0.0456)	(0.0421)
POLICY	0.00235**	0.00273**	0.0000276
	(0.00112)	(0.00124)	(0.00113)
NORTH	0.0332	-0.0675	-0.0603
	(0.0966)	(0.107)	(0.0940)
CENTRE	-0.0477	-0.286**	0.00640
	(0.107)	(0.121)	(0.104)
SOUTH	0	0	0
	(.)	(.)	(.)
Constant	-1.486***	-1.769***	-1.200***
	(0.142)	(0.161)	(0.136)
N.Obs.	3265	3265	3265

Notes: Reported are Probit Model estimations. Standard errors in parentheses . *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Table A.7 Robustness check in ATECO subsamples: Innovation to reduce waste per output produced

Sector:	Food Industry	Textile Industry	Clothing manufacture	Manufacture of leather goods	Wood industry excluding furniture	Paper Industry	Press	Manufacture of chemicals	Manufacture of rubber articles	Manufacture of other mineral products
Sectors' technological intensity:	LT	LT	LT	LT	LT	LT	LT	MHT	MLT	MLT
ATECO code:	10	13	14	15	16	17	18	20	22	23
Dependent variable:	WASRED	WASRED	WASRED	WASRED	WASRED	WASRED	WASRED	WASRED	WASRED	WASRED
SIZE	0.000545	-0.00292	-0.0000324	0.000264	-0.00181	0.0116*	0.00413	0.00207	-0.00223	0.00241
	(0.00271)	(0.00364)	(0.00648)	(0.00317)	(0.00606)	(0.00653)	(0.00607)	(0.00411)	(0.00310)	(0.00382)
AGE	0.000700	0.00469	-0.000978	0.00617	0.00235	0.000207	-0.00854	0.0117	-0.00586	-0.0114*
	(0.00328)	(0.00542)	(0.00598)	(0.00774)	(0.00646)	(0.00913)	(0.00970)	(0.00791)	(0.00664)	(0.00636)
RED	0.682***	0.621**	0.811***	0.456	0.532*	-0.150	0.254	0.895**	0.777***	0.583
	(0.192)	(0.289)	(0.295)	(0.316)	(0.323)	(0.420)	(0.397)	(0.381)	(0.219)	(0.356)
INDUSTRY	0.0730	0.666**	0.317	0.462	0.256	0.872**	0.843**	0.177	-0.0499	0.0917

4.0										
	(0.249)	(0.334)	(0.448)	(0.367)	(0.382)	(0.411)	(0.388)	(0.439)	(0.223)	(0.472)
PEER	0.125	0.620**	0.594*	0.0893	0.449	0.195	1.046**	0.695	0.331	0.0877
	(0.179)	(0.302)	(0.310)	(0.308)	(0.318)	(0.413)	(0.457)	(0.463)	(0.212)	(0.354)
COSTWAS	0.301*	0.334	-0.384	0.0128	0.526***	0.00207	-0.0982	0.176	0.225*	0.665***
	(0.159)	(0.226)	(0.386)	(0.232)	(0.179)	(0.216)	(0.256)	(0.218)	(0.126)	(0.248)
POLICY	0.00480*	0.00730	-0.00364	-0.000741	-0.0108	0.000559	0.00978	0.00455	-0.00210	0.00744
	(0.00286)	(0.00597)	(0.00611)	(0.00628)	(0.00708)	(0.00666)	(0.00636)	(0.00915)	(0.00465)	(0.00589)
NORTH	0.0685	0.117	-0.0308	0.395	-0.266	0.104	0.0783	-0.0815	-0.0199	0.935
	(0.208)	(0.944)	(0.438)	(0.515)	(0.371)	(0.636)	(0.488)	(0.844)	(0.411)	(0.659)
CENTRE	-0.0386	-0.493	-0.178	-0.244	0	-0.0674	-0.337	-1.210	-0.0807	0.663
	(0.255)	(0.907)	(0.467)	(0.531)	(.)	(0.799)	(0.790)	-1.021	(0.473)	(0.657)
SOUTH	0	0	0	0	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
Constant	-1.557***	-2.198*	-1.534***	-1.526**	-1.073*	-1.657**	-2.237***	-2.363**	-0.857	-2.611***
	(0.288)	-1.124	(0.553)	(0.672)	(0.630)	(0.778)	(0.680)	-1.014	(0.539)	(0.845)
Observations	298	137	142	127	112	65	91	70	208	113

Sector:	Metallurgy	Manufacture of metal products	Manufacture of pc and electronic products	Manufacture of electrical equipment	Manufacture of machinery and equipment	Manufacture of motor vehicles	Manufacture of other transport equipment	Manifacture of furniture	Other manifacturing industries	Machine repair, maintenance and installation
Sectors' technological intensity:	MLT	MLT	HT	MHT	MHT	MHT	MHT	LT	LT	MLT
ATECO code:	24	25	26	27	28	29	30	31	32	33
Dependent variable:	WASRED	WASRED	WASRED	WASRED	WASRED	WASRED	WASRED	WASRED	WASRED	WASRED
SIZE	-0.00560	-0.00167	0.00373	0.00282	0.000512	-0.00236	-3.357	-0.0106*	0.00375	-0.0106*
	(0.00524)	(0.00194)	(0.00493)	(0.00366)	(0.00192)	(0.00438)	(.)	(0.00606)	(0.00804)	(0.00635)
AGE	0.0109	0.00322	-0.000451	0.00482	-0.000322	0.0111	0.204	0.0138**	-0.00162	0.00517
	(0.00943)	(0.00299)	(0.00903)	(0.00801)	(0.00297)	(0.0113)	(.)	(0.00609)	(0.00876)	(0.00773)
RED	1.372**	0.768***	-0.122	0.301	0.295*	1.139**	113.5	1.329***	0.656*	0.245
	(0.542)	(0.120)	(0.330)	(0.266)	(0.167)	(0.580)	(.)	(0.340)	(0.377)	(0.307)
INDUSTRY 4.0	-0.502	0.314***	0.236	0.286	0.0101	-1.034	-8.443	1.117***	0.206	-0.452
	(0.584)	(0.121)	(0.363)	(0.319)	(0.185)	(0.662)	(.)	(0.339)	(0.515)	(0.461)
PEER	0.338	0.0935	0.260	0.299	0.521***	-0.730	-0.124	-0.233	0.543	0.268
	(0.648)	(0.114)	(0.376)	(0.298)	(0.185)	(0.499)	(.)	(0.361)	(0.396)	(0.285)
COSTWAS	-0.717	0.205***	0.452	0.0916	0.253	2.204***	55.36	0.432**	0.163	0.386*
	(0.604)	(0.0770)	(0.280)	(0.284)	(0.158)	(0.730)	(.)	(0.180)	(0.466)	(0.218)
POLICY	0.00345	0.00457*	0.000657	0.00795	-0.00546	-0.00775	0.0299	-0.00558	-0.00446	0.00439
	(0.0105)	(0.00249)	(0.00584)	(0.00546)	(0.00419)	(0.00935)	(.)	(0.00898)	(0.0107)	(0.00558)
NORTH	0	-0.112	0.252	-0.364	0.00461	-0.460	0	-0.206	-0.295	0.0647
	(.)	(0.215)	(0.586)	(0.427)	(0.436)	-1.024	(.)	(0.473)	(0.405)	(0.428)
CENTRE	0	-0.135	0.373	-0.632	0.236	1.155	48.66	-0.441	0	0.0890
	(.)	(0.238)	(0.635)	(0.488)	(0.486)	-1.091	(.)	(0.565)	(.)	(0.469)
SOUTH	0	0	0	0	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
Constant	-2.001**	-1.517***	-1.692**	-1.644***	-1.349***	-0.739	-17.40	-1.571***	-1.045	-1.297**
	(0.801)	(0.281)	(0.702)	(0.596)	(0.514)	-1.237	(.)	(0.556)	(0.776)	(0.576)
Observations	46	806	93	143	358	38	21	115	70	135

Notes: Reported Probit Model. Standard errors in parentheses . *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Low Technology sector(LT); Medium-Low Technology sector (MLT); Medium-High Technology sector (MHT); High Technology sector (HT). ATECO 11, 12, 19,21 not reported due to insufficient observations.

Table A.8 Robustness check in ATECO subsamples: Innovation to reuse waste within own productive process

Sector:	Food Industry	Textile Industry	Clothing manufacture	Manufacture of leather goods	Wood industry excluding furniture	Paper Industry	Press	Manufacture of chemicals	Manufacture of rubber articles	Manufacture of other mineral products
Sectors' technological intensity:	LT	LT	LT	LT	LT	LT	LT	MHT	MLT	MLT
ATECO code:	10	13	14	15	16	17	18	20	22	23
Dependent variable:	WASREUSE	WASREUSE	WASREUSE	WASREUSE	WASREUSE	WASREUSE	WASREUSE	WASREUSE	WASREUSE	WASREUSE
SIZE	-0.0000468	0.00337	-0.0147	-0.000222	0.00145	0.00871	0.0354**	0.00904**	-0.00280	0.000579
	(0.00319)	(0.00306)	(0.0136)	(0.00353)	(0.00536)	(0.00603)	(0.0152)	(0.00400)	(0.00313)	(0.00401)
AGE	0.00482	0.00660	0.0105	-0.00235	-0.00915	0.00900	0.0147	0.00588	-0.0000713	-0.00598
	(0.00342)	(0.00617)	(0.00698)	(0.00892)	(0.00798)	(0.00889)	(0.0115)	(0.00861)	(0.00652)	(0.00714)
RED	0.551**	0.518*	1.148**	-0.00211	0.352	0.311	0.669	0.458	0.522**	0.496
	(0.218)	(0.296)	(0.460)	(0.368)	(0.395)	(0.388)	(0.578)	(0.428)	(0.216)	(0.366)
INDUSTRY 4.0	-0.188	0.335	0	0.223	0.520	0.673	0.904	0.286	0.182	0.412
	(0.277)	(0.364)	(.)	(0.401)	(0.496)	(0.414)	(0.601)	(0.473)	(0.216)	(0.459)
PEER	0.116	0.121	0.558	0.153	-0.127	0.153	2.545***	0.734	0.203	0.361
	(0.212)	(0.336)	(0.581)	(0.363)	(0.334)	(0.447)	(0.669)	(0.602)	(0.206)	(0.372)
COSTWAS	0.299*	-0.386	0	-0.547	0.380	-0.209	0.747*	0.312	0.0381	0.831***
	(0.160)	(0.328)	(.)	(0.375)	(0.237)	(0.208)	(0.399)	(0.257)	(0.129)	(0.264)
POLICY	0.00296	0.0100	-0.0278***	-0.00702	-0.00651	-0.00450	-0.00252	0.0111	0.00552	0.00778
	(0.00330)	(0.00624)	(0.0103)	(0.00889)	(0.00880)	(0.00653)	(0.00861)	(0.00974)	(0.00459)	(0.00474)
NORTH	-0.119	0.163	-0.754	0.778**	0.146	0.0289	-2.317***	-0.511	0.474	0.343
	(0.249)	(0.370)	(0.582)	(0.329)	(0.582)	(0.640)	(0.712)	(0.874)	(0.436)	(0.530)
CENTRE	-0.0208	0	-1.247	0	0	0.126	0	-0.850	0.264	-0.413
	(0.295)	(.)	(0.799)	(.)	(.)	(0.822)	(.)	(0.942)	(0.486)	(0.687)
SOUTH	0	0	0	0	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
Constant	-1.842***	-2.453***	-0.623	-1.282**	-0.853	-1.687**	-3.450***	-2.503**	-1.554***	-2.378***
	(0.311)	(0.636)	(0.591)	(0.567)	(0.836)	(0.858)	-1.006	(0.985)	(0.595)	(0.663)
Observations	298	130	113	109	105	65	84	70	208	113

Sector:	Metallurgy	Manufacture of metal products	Manufacture of pc and electronic products	Manufacture of electrical equipment	Manufacture of machinery and equipment	Manufacture of motor vehicles	Manifacture of furniture	Other manifacturing industries	Machine repair, maintenance and installation
Sectors' technological intensity:	MLT	MLT	HT	MHT	MHT	MHT	LT	LT	MLT
ATECO code:	24	25	26	27	28	29	31	32	33
Dependent variable:	WASREUSE	WASREUSE	WASREUSE	WASREUSE	WASREUSE	WASREUSE	WASREUSE	WASREUSE	WASREUSE
SIZE	-0.00491	-0.00829**	-0.0109	0.00418	0.00325	-4.553	-0.0150	0.00711	-0.00947
	(0.00580)	(0.00378)	(0.00914)	(0.00392)	(0.00216)	(.)	(0.0116)	(0.00809)	(0.00618)
AGE	0.00838	0.00222	-0.00883	-0.00432	0.00418	13.12	0.0297**	0.0119	0.0153
	(0.00903)	(0.00327)	(0.0139)	(0.00757)	(0.00389)	(.)	(0.0133)	(0.00895)	(0.0112)
RED	1.003*	0.539***	0.225	0.521*	0.415**	0	1.590***	0.730*	0
	(0.540)	(0.138)	(0.406)	(0.291)	(0.202)	(.)	(0.462)	(0.407)	(.)
INDUSTRY 4.0	0.503	0.367***	-0.0359	0.139	-0.180	0	0.700	-1.477**	0.180
	(0.553)	(0.136)	(0.540)	(0.338)	(0.221)	(.)	(0.506)	(0.638)	(0.468)
PEER	-0.108	-0.103	0.654	-0.148	0.191	-875.7	-0.0498	1.315**	0.439
	(0.563)	(0.125)	(0.514)	(0.300)	(0.207)	(.)	(0.423)	(0.536)	(0.424)
COSTWAS	0.0430	0.180**	0.588*	0.516*	-0.112	524.6	0.180	0.0939	0.0898

	(0.500)	(0.0898)	(0.334)	(0.281)	(0.238)	(.)	(0.271)	(0.484)	(0.266)
POLICY	0.00946	0.00856***	0.0000562	0.00306	-0.00536	45.92	-0.0380***	-0.0000943	-0.00385
	(0.0114)	(0.00273)	(0.00943)	(0.00581)	(0.00487)	(.)	(0.0142)	(0.0117)	(0.00619)
NORTH	-0.368	-0.379*	0.279	0.636	-0.0272	0	-1.792**	0.229	-0.316
	(0.651)	(0.220)	(0.611)	(0.460)	(0.510)	(.)	(0.883)	(0.454)	(0.497)
CENTRE	0	-0.700***	0	0.418	-0.305	0	-1.366	0	0.0459
	(.)	(0.271)	(.)	(0.594)	(0.579)	(.)	(0.837)	(.)	(0.559)
SOUTH	0	0	0	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
Constant	-1.901*	-1.394***	-2.035**	-2.208***	-1.626***	-1738.7	-0.330	-2.628***	-1.349**
	(0.974)	(0.309)	(0.920)	(0.600)	(0.562)	(.)	(0.744)	(0.928)	(0.590)
Observations	49	806	84	143	358	10	115	70	103

Notes: Reported Probit Model. Standard errors in parentheses . *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Low Technology sector(LT); Medium-Low Technology sector (MLT); Medium-High Technology sector (MHT); High Technology sector (HT). ATECO 11, 12, 19,21, 30 not reported due to insufficient observations.

Table A.9 Robustness check in ATECO subsamples: Innovation for delivery waste to other companies

Sector:	Food Industry	Beverage industry	Textile Industry	Clothing manufacture	Manufacture of leather goods	Wood industry excluding furniture	Paper Industry	Press	Manufacture of chemicals	Manufacture of rubber articles
Sectors' technological intensity:	LT	LT	LT	LT	LT	LT	LT	LT	MHT	MLT
ATECO code:	10	11	13	14	15	16	17	18	20	22
Dependent variable:	WASDEL	WASDEL	WASDEL	WASDEL	WASDEL	WASDEL	WASDEL	WASDEL	WASDEL	WASDEL
SIZE	0.00395*	0.895	0.00623*	0.00665	-0.00376	0.00530	0.00871	-0.00486	0.00250	0.000404
	(0.00221)	(.)	(0.00367)	(0.00599)	(0.00370)	(0.00557)	(0.00635)	(0.0121)	(0.00410)	(0.00250)
AGE	-0.00485	-0.0698	-0.0102	0.00440	0.00581	0.0110*	-0.0141	0.00575	0.00725	-0.00496
	(0.00327)	(.)	(0.00683)	(0.00486)	(0.00896)	(0.00636)	(0.0124)	(0.0101)	(0.00798)	(0.00618)
RED	0.188	-7.937	0.0762	0.821***	-0.409	0.256	-0.582	0.500	0.893**	0.0611
	(0.202)	(.)	(0.312)	(0.295)	(0.393)	(0.318)	(0.403)	(0.483)	(0.443)	(0.216)
INDUSTRY4.0	-0.00103	4.992	0.346	0.274	0.242	-0.706*	0.876*	0.333	0.414	0.389*
	(0.268)	(.)	(0.344)	(0.414)	(0.441)	(0.419)	(0.474)	(0.482)	(0.443)	(0.216)
PEER	0.568***	0	0.0860	0.174	0.192	0.135	0.310	1.527***	0.00679	0.329
	(0.197)	(.)	(0.294)	(0.302)	(0.348)	(0.280)	(0.401)	(0.480)	(0.495)	(0.208)
COSTWAS	0.252	7.149	-0.101	0.309	0.532**	0.574***	-0.253	0.731**	0.0688	0.120
	(0.155)	(.)	(0.230)	(0.368)	(0.245)	(0.180)	(0.188)	(0.324)	(0.243)	(0.132)
POLICY	0.00595**	1.153	-0.00811	-0.00360	0.00518	-0.00158	-0.000125	0.0132	-0.00354	-0.000629
	(0.00280)	(.)	(0.00644)	(0.00621)	(0.00712)	(0.00553)	(0.00554)	(0.00877)	(0.0132)	(0.00470)
NORTH	-0.120	41.81	-0.294	-0.0307	0.359	-0.0243	-0.188	-0.110	0.704	0.369
	(0.217)	(.)	(0.320)	(0.479)	(0.450)	(0.470)	(0.547)	(0.561)	(0.664)	(0.443)
CENTRE	0.177	79.84	0	0.109	0.333	0.151	-0.606	0	0	0.847*
	(0.248)	(.)	(.)	(0.466)	(0.413)	(0.574)	(0.655)	(.)	(.)	(0.487)
SOUTH	0	0	0	0	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
Constant	-1.653***	-119.3	-0.430	-1.872***	-2.183***	-1.559**	-0.357	-3.516***	-2.471**	-1.336**
	(0.278)	(.)	(0.509)	(0.580)	(0.643)	(0.653)	(0.640)	(0.877)	-1.037	(0.619)
Observations	298	10	130	142	127	126	65	84	66	208
Sector:	Manufacture of other mineral products	Metallurgy	Manufacture of metal products	Manufacture of pc and electronic products	Manufacture of electrical equipment	Manufacture of machinery and equipment	Manufacture of motor vehicles	Manifacture of furniture	Other manifacturing industries	Machine repair, maintenance and installation

Sectors' technological intensity:	MLT	MLT	MLT	HT	MHT	MHT	MHT	LT	LT	MLT
ATECO code:	23	24	25	26	27	28	29	31	32	33
Dependent variable:	WASDEL	WASDEL	WASDEL	WASDEL	WASDEL	WASDEL	WASDEL	WASDEL	WASDEL	WASDEL
SIZE	0.000892	-0.00788	-0.00515**	0.00609	-0.000736	0.000167	-0.0231	-0.0154*	-0.0121	-0.0111*
	(0.00381)	(0.00623)	(0.00203)	(0.00515)	(0.00325)	(0.00218)	(0.0156)	(0.00868)	(0.0112)	(0.00664)
AGE	0.00502	0.000862	0.00157	-0.00591	-0.00335	0.00555*	0.186***	0.0139**	0.00871	0.0127
	(0.00569)	(0.00789)	(0.00291)	(0.00917)	(0.00955)	(0.00303)	(0.0603)	(0.00568)	(0.00911)	(0.00916)
RED	0.000692	-0.124	0.261**	-0.0176	0.600**	0.00125	6.707***	0.600*	-0.279	-0.277
	(0.390)	(0.457)	(0.124)	(0.378)	(0.289)	(0.174)	-2.417	(0.312)	(0.492)	(0.361)
INDUSTRY 4.0	0.121	0.0474	0.379***	0.229	0.0124	-0.0121	1.343	0.369	1.228**	-0.249
	(0.488)	(0.459)	(0.120)	(0.425)	(0.332)	(0.197)	(0.915)	(0.400)	(0.523)	(0.355)
PEER	1.000***	1.208**	0.169	0.361	0.289	0.150	-3.388***	-0.339	0.251	0.131
	(0.312)	(0.610)	(0.113)	(0.402)	(0.322)	(0.169)	-1.053	(0.300)	(0.367)	(0.335)
COSTWAS	0.0796	0.906**	0.0761	0.308	0.00287	0.262	-7.980***	0.0931	0.482	0.587***
	(0.271)	(0.406)	(0.0872)	(0.275)	(0.312)	(0.161)	-2.663	(0.177)	(0.385)	(0.209)
POLICY	0.00554	-0.0102	0.00351	-0.0137	0.00628	-0.00524	-0.0874***	-0.00779	-0.00854	-0.00935
	(0.00477)	(0.0101)	(0.00252)	(0.00940)	(0.00620)	(0.00416)	(0.0317)	(0.00818)	(0.00919)	(0.00739)
NORTH	0.237	-0.774	-0.161	-0.187	0.157	-0.0309	-9.453***	-0.288	-0.750	-0.329
	(0.497)	(0.669)	(0.194)	(0.510)	(0.473)	(0.399)	-2.613	(0.617)	(0.662)	(0.455)
CENTRE	0.316	0	-0.396*	0	0.100	0.263	-10.12***	0.0153	-1.376*	0.265
	(0.514)	(.)	(0.235)	(.)	(0.536)	(0.457)	-2.906	(0.669)	(0.752)	(0.526)
SOUTH	0	0	0	0	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)	(.)
Constant	-2.531***	-0.567	-1.205***	-0.849	-1.920***	-1.173**	2.902***	-0.636	-0.299	-0.761
	(0.603)	(0.860)	(0.255)	(0.774)	(0.635)	(0.474)	-1.052	(0.675)	-1.135	(0.530)
Observations	113	49	806	84	143	358	38	115	77	135

Notes: Reported Probit Model. Standard errors in parentheses . *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level. Low Technology sector(LT); Medium-Low Technology sector (MLT); Medium-High Technology sector (MHT); High Technology sector (HT). ATECO 12, 19,21, 30 not reported due to insufficient observations.

3. What do Circular Innovator firms look like in Emilia-Romagna? A cluster analysis of firms innovating in the circular economy

3.1 Introduction

With the European Green Deal further impetus was given to the role of CE in shaping current systems of production toward sustainable models, able to speed up economic growth while addressing major environmental challenges. The decoupling of economic growth from resource use and the shift to circular systems of production and consumption is indeed recognized as key to achieving EU climate neutrality by 2050 and ensuring a green recovery from COVID-19. Clearly, for some MSs and regions, achieving climate neutrality by 2050 will be more challenging than for others. Indeed, some are more dependent on fossil fuels or are characterized by a high number of employees in carbon-intensive industries. Nevertheless, recent circumstances, such as the pandemic and the Ukrainian crisis, have further highlighted the opportunities that the CE can also offer to alleviate our economy's dependence on energy and raw materials from third countries, thus making it more resilient to external shocks (MITE, 2022).

In Italy, for example, where internal raw material supply is scarce and markets are geographically marginal compared to central Europe, the CE represents a strategic objective (MITE 2022). Strengthening the industrial base by using the *green push* will allow to jointly face the spreading of new global protectionism, the environmental emergence, and the effects of the new digital revolution. From this perspective, the Italian industrial sector is called to play the role of driver of change, growth, and innovation. Italian firms shall rethink and create new BMs compatible with a circular approach and put innovation at the centre of this path. This concerns a double dimension. On the one hand, managing resources more efficiently, safely, and extending their use (*upstream dimension*). On the other hand, reducing residuals and allowing their re-use and return to new productive process (*downstream dimension*).

Proceeding from theory to practice, some legitimate questions have been raised among the stakeholders and the scientific community. *Which are the innovations for CE* (Rosa et al., 2019)? *Which CBMs will emerge* (Bocken et al., 2016)? *and which factors are able to spur/hinder circular practices* (Stumpf et al., 2021; Pieroni et al., 2019; Hina et al., 2022)?.

Despite this strand of research is rather new, many studies are now addressing these questions. However, evidence on the determinants of CI application at firm level is still scant as suggested in Cainelli et al., (2020). De Jesus et al., (2018) state that although CE and EI are strictly related, «not all EI is linked to a CE, and not all dimensions of CE require innovation» (p. 3000). Therefore, the discussion on CIs needs reflections in its own right. In addition, bearing in mind that *one size does not fit all*, there is a need for studies taking into account the high heterogeneity across firms and industries across geographical spaces, which will help to undertake ad-hoc and targeted interventions.

Against this background, the present study, adopting a micro perspective, will attempt to shed light on the main features of circular innovative firms in order to gather information on which characteristics seem to best suit the ability of firms to take a step toward circularity. Particularly, this work will provide an exploratory examination of different firm profiles that emerged in ER. ER is part of the cluster of the most EU developed regions, together with Catalongna, Rone-Alpes and Baden-Württemberg (Confindustria 2020). In addition, as for innovation, according to the RIS (Regional Innovation Scoreboard), the ER is in the first ranking compared to other Italian regions, and in the 76th position in the EU ranking (240 regions). Therefore, ER represents an interesting model to study.

The study relies on a new dataset containing information on 1564 firms situated in ER. Data have been gathered during a survey organized in 2020 by CERCIS the Centre for Research on CE, Innovation and SMEs of the University of Ferrara, which allows gaining descriptive insights on firms' demographic characteristics, innovation, green innovation introduction, and R&D investments. Cluster analysis is subsequently applied to assign each firm to different groups, whose heterogeneity depends on their levels of innovativeness. This allows to capture the inner features of firms belonging to each cluster and therefore highlights the distinctive traits of non-innovators and innovators, with special attention to circular innovators. This process has at least two important implications. First, it will enrich the broad discussion on CE drivers and barriers. Second, the focus on the specific case of ER is relevant since it provides a clear picture of how CE is taking shape in this territory and among which firms’ typologies, this would eventually provide some food for thought for the development of future legislation in which local governments may be interested.

The chapter is structured as follows: Section 3.2 presents the context and characteristics of the ER productive system. Section 3.3 describes the empirical approach, including the presentation of data collection, the dataset, and the cluster analysis. Section 3.4 shows and discusses the results of the analysis. Section 3.5 concludes with some implications for policy.

3.2 The Emilia-Romagna: industrial context and characteristics

In the past, the ER region has been described as an example of industrial development. Brusco (1982) has, for example, demonstrated how the social characteristics and values of its SMEs systems and especially districts, have been pivotal for its competitiveness, growth and resilience to crisis (Bianchi and Labory, 2014).

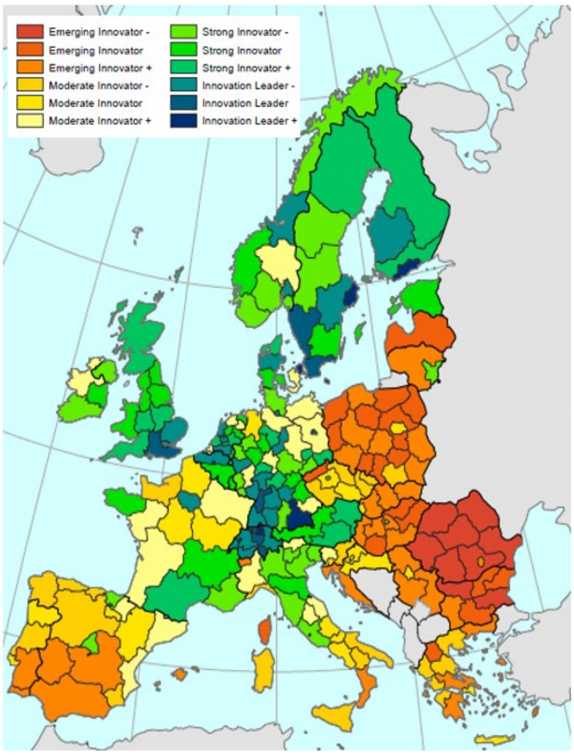
This section firstly defines the overall production structure of ER firms. Then, a focus on the ER innovation performance will be presented, relying on the EU RIS.

According to a recent report of Confindustria, the ER is fourth in Italy for the number of firms (450 thousand) and production generated (330 million euros, which corresponds to 9.5% of the overall national production), behind Lombardy, Lazio and Veneto. 37% of firms' production derives from manufacturing and, 6% from construction. ER shows a strong specialization in mechanics, food, and in the automotive sector and it additionally relies on the district primates of ceramics and biomedicals. The strong dimensional polarisation towards micro and small size firms is, however, a peculiar aspect of the ER production structure. Accordingly, business demography is characterized by the presence of many small firms with a higher average age than their Italian peers. The higher average age is also associated with higher average seniority in top management positions. Indeed, ER firms have the highest percentage of senior figures over 60 years old and the lowest percentage under 40 years old, which in the medium term obviously raises generational changeover issues.

These structural features influence the ER performances compared to the main European competitor regions. Indeed, while ER is one of the best performers in terms of productivity at the national level, it loses positions when enters international competition. Another critical aspect regards the clear split among firms reporting good economic and financial results and firms in critical financial conditions. According to Confindustria, over the last three-year period, 31.4% of firms have registered a turnover growth of more than 10%, but similarly, 24% of firms have reported a negative variation. On the other hand, ER firms have demonstrated a strong ability to operate within international networks. ER is indeed part of the top 10 European regions by export size, with more than 22.000 exporting firms belonging to different sectors, from mechanical production to the fashion industry, food, and bio-medical sectors. These results make internationalization one of the main points of excellence and competitive advantage for ER firms.

As for the innovative performance of the region, the EU RIS shows how ER ranks in the national and international classification[5]. The RIS compares 240 EU regions using a composite indicator (the Summary Innovation Index) and relying on the methodology adopted by the EU Innovation Scoreboard, aimed at comparing national performances. The RIS is estimated on the basis of four macro areas and twelve innovative dimensions, which in total correspond to 21 different indicators. For the scope of the analysis, a selection of indicators is taken into account, namely R&D expenditure in the business sector as a percentage of GDP, SMEs introducing product innovation as a percentage of total SMEs, SMEs introducing process innovation as a percentage of total SMEs, patent application per billion GDP, and employment in innovative SMEs.

Fig. 3.1 Ranking of EU and Italian performances according to RIS 2021.



NUTS	Region	RII	Rank	Group	Change
ITC1	Piemonte	97.8	115	Moderate +	25.0
ITC2	Valle d'Aosta/ Vallée d'Aoste	67.4	179	Emerging +	14.7
ITC3	Liguria	88.3	136	Moderate	28.2
ITC4	Lombardia	102.3	97	Strong -	27.9
ITH1	Provincia Autonoma Bolzano/ Bozen	94.8	120	Moderate +	23.8
ITH2	Provincia Autonoma Trento	107.1	85	Strong -	29.8
ITH3	Veneto	102.8	95	Strong -	29.0
ITH4	Friuli-Venezia Giulia	106.6	89	Strong -	25.1
ITH5	Emilia-Romagna	109.4	76	Strong	34.2
ITI1	Toscana	101.3	98	Strong -	27.9
ITI2	Umbria	98.8	109	Moderate +	29.2
ITI3	Marche	90.6	130	Moderate +	26.6
ITI4	**Lazio**	100.4	104	Strong -	26.6
ITF1	Abruzzo	84.7	142	Moderate	22.7
ITF2	Molise	82.9	146	Moderate	26.4
ITF3	Campania	83.3	144	Moderate	30.0
ITF4	Puglia	74.1	164	Moderate -	21.6
ITF5	Basilicata	79.7	154	Moderate -	30.1
ITF6	Calabria	68.2	174	Emerging +	20.1
ITG1	Sicilia	70.3	173	Moderate -	21.9
ITG2	Sardegna	70.4	172	Moderate -	19.5

RIS (2021)

Fig. 3.1 shows that ER is a Strong Innovator[6]. Compared to other Italian regions in terms of innovation, ER is in the first ranking, while in the European ranking of 240 regions, ER is

[5] The Regional Innovation Scoreboard is compiled annually by the European Commission (Internal Market, Industry, Entrepreneurship and SME) as a tool for monitoring innovation in the European Innovation Scoreboard.

[6] Europe's regions are grouped into four innovation performance groups according to their performance on the Regional Innovation Index relative to that of the EU. *Innovation Leaders* includes 38 regions performing above 125% of the EU average. *Strong Innovators* includes 67 regions performing between 100% and 125% of the EU average. *Moderate Innovators* includes 68 regions performing between 70% and 100% of the EU average. *Emerging Innovators* includes 67 regions performing below 70% of the EU average.

in the 76th position. Considering the various indicators, ER is in 3rd place among Italian regions and in 38th place in the EU for the number of SMEs introducing product innovations, and it is 3rd among Italian Regions and 20th for the number of SMEs introducing process innovations. In addition, ER is situated in the 1st position in Italy for the percentage of employees in innovative SMEs, and 19th in the EU. As for the patent activity, ER is in the first position in Italy in terms of the number of patents submitted to the EPO (between 2009 and 2017, 16% out of 25.000 applications submitted by Italian firms, were from ER). More than one patent out of two is related to the technological area of mechanical engineering. However, a partial repositioning of the regional patent's activity is occurring in the last few years guided by the increasing automation of production process, with very marked growth in the field of Information and Communication Technology (ICT) and optical and measuring instruments, fundamental to go on the direction of the productive automation. Despite this, broadly, outside the mechanical engineering sector, innovative activity is limited. Indeed, in terms of patent activity ICT, metal products and electro-medical companies are far behind those in the mechanical sector, probably due to the small size of firms in this sector (Confindustria, 2020). Expanding the analysis of innovative activity, the incidence of R&D expenditure on GDP (2%) is higher than that of other Italian regions, but far from that of European leaders (Baden-Württemberg is 5.6%) (Confindustria, 2020). According to RIS, indeed, ER is second among Italian regions, but in 48th position among EU regions.

Summing up, companies with a higher average age than their Italian peers, better capitalised and with a strong specialisation in mechanics (across all the main production chains, from food to automotive), intense patenting activity in the fields of robotics and mechanical engineering, and high internationalization are the strong points to leverage for future development plans. Small companies, little managerial and managerial turnover, low penetration of innovative activities in the ICT field, a consistent share of firms in a financially fragile situation, and inadequate spending on R&D are, however, the critical aspects to be overcome in order not to lose the wealth and industrial variety of the territory

3.3 Empirical Analysis

The empirical analysis models regional firms according to their level of innovativeness expressed through the identification of different clusters. The focus is on finding common patterns and characteristics among firms, enabling a representation of innovators *Vs* non-innovators and innovators *Vs* circular innovators. This eventually enables the identification of potential drivers and barriers that can either play, alone or in combination, as deterrents or facilitators of innovation, with special attention toward CI.

3.3.1 Data collection

This study will resort to survey data collected on Emilia- Romagna manufacturing firms, with at least ten employees. The survey has been organized in 2020 by the survey company Izi s.p.a. Data have been gathered through a Computer Assisted Web Interview (CAWI), by providing firms with a questionnaire. The period of time covered is the three-years period 2017-2019. The final sample counts 1613 respondent companies, and it has been subsequently stratified by geographical localization (macro area, Istat), sector (technological intensity, Eurostat), dimension (10-49 employees; 50-249 employees; >250 employees).
The questionnaire is structured in the following four sections: 1) Firms' characteristics 2) Innovation and Investments 3) Circular Economy 4) COVID-19 impact and strategies.

The first section is aimed at collecting firms' general data on geographical localization, sector classification, district, group, and supply chain of belonging, firms' turnover (2017-2019), firms' age, export level, number of employees (2017-2019) and rate of those employed in R&D activities. The second section investigates firms' innovation activity in the three-year period 2017-2019, distinguishing between process and product innovation and their level of radicalness, depending on whether the EI is new to the firm, to the supply chain, to the sector or to the global market. Additionally, it aims at measuring the main obstacles, drivers, and timing of the innovation adoption process. On the other hand, it investigates firms' investment capacity in R&D, R&D devoted to reducing the environmental impacts of production, and patents' adoption, in the three-year period 2017-2019. The third part of the questionnaire is specifically focused on CE and CI adoption in the three-year period 2017-2019. The types of CI included are innovations focused on a) water reduction; b) raw material reduction; c) changing design to reduce material use; d) renewable energy use; e) electrical energy reduction; f) design change to increase products' durability; g) design change to increase products' repairability; h) design change to increase products' recyclability; i) substitution of materials with high environmental impacts with sustainable materials; l) reducing waste generation per output produced; m) reusing waste within own firm productive process; n) delivery of own waste to other companies in order to be used as input in their production process. This section also scrutinizes potential drivers for innovation adoption, making reference to market *vs*. non-market instruments and main financial instruments used to undertake CI adoption. Finally, the last section examines the impacts produced by the outbreak of the Covid-19 crisis in terms of turnover, innovation and green innovation investments, training activities, and main strategies to overcome the economic shock.

3.3. 2 Cluster analysis methodology

Cluster analysis is applied to organize data and reveal the existence of diverse groups of firms based on their innovation adoption level across the ER region. Cluster analysis is performed, indeed, in order to profile groups of observations that are homogeneous within the same cluster and distinct among different clusters. As suggested in Hair et al. (2009), the study adopts a two-steps cluster procedure. First, an agglomerative hierarchical cluster analysis has been led to identify the number of clusters. Then, the results have been used as a starting point to perform a non-hierarchical clustering, which allows distributing the number of observations into clusters, and thus identifies different firms' profiles.

The variables have been chosen through the application of an Exploratory Factor Analysis (EFA) on the sample of questions. EFA allows to analyse the structure of correlations among a large number of variables. Factors can be employed both to reduce the number of variables in large datasets or to describe a structure among the variables under analysis (Hair et al. 2009). In this study, EFA has been employed to find factors that outline a conceptual pattern within the data and to avoid multicollinearity problems among variables in the cluster variate. To justify the application of EFA, a preliminary visual analysis with a matrix of correlation has been executed. The data matrix shows sufficient correlation by excluding some variables (The complete list of variables is available in Appendix **Table B.1**). This has been further confirmed by Barlett's test of sphericity, which demonstrates that the correlation matrix has significant correlations, and a KMO at 0.81 (in Appendix **Table B.2**). The matrix of factors has been subsequently estimated through a component factor analysis and only the factors having eigenvalues greater than 1 have been considered significant. This reflects the results derived through the application of a scree plot, indicating the number of factors to retain at the fourteenth factor, when the shape of the curve starts to decline sharply. The factor matrix has been subsequently rotated orthogonally in order to simplify the factor structure and its interpretation. The resulting fourteen factors are reported in **Table 3.1**, and the corresponding scores have been used as cluster variables. The final sample contains 1564 observations.

Table 3.1 Exploratory Factor Analysis Results

Factors	Factor description	N. Obs.	Min	Max
Factor 1	R&D employees	1.564	-4.525.588	1.409.161
Factor 2	Firm dimension	1.564	-1.510.087	1.621.663
Factor 3	Product Design – Circular Innovation	1.564	-2.139.308	6.075.441
Factor 4	Standard Innovation	1.564	-2.829.573	2.973.973
Factor 5	Resource Efficiency – Circular Innovation	1.564	-2.310.572	5.771.248
Factor 6	Internationalization	1.564	-2.395.808	2.536.341
Factor 7	Clean Resources – Circular Innovation	1.564	-2.990.681	5.759.839
Factor 8	Industrial symbiosis – Circular Innovation	1.564	-2.369.889	4.446.009
Factor 9	R&D Investments	1.564	-6.939.523	6.506.308
Factor 10	Innovation obstacles	1.564	-2.275.367	451.541
Factor 11	Innovation financing instruments	1.564	-1.839.836	1.408.243
Factor 12	Firms' Awareness	1.564	-3.001.432	5.989.458
Factor 13	Agglomeration	1.564	-3.359.642	6.374.056
Factor 14	Resilience	1.564	-6.398.024	4.550.595

Having identified the factors, the complete linkage algorithm has been used to perform the hierarchical cluster analysis. The algorithm computes the Euclidean distance in clustering variables based on the maximum distance between observations in each cluster. This procedure leads to the identification of five clusters, through the support of a series of statistical tests Pseudo T-squared statistics, Je(2)/Je(1) statistics and Chalinski-Harabasz pseudo F statistics (For details please refer to Appendix **Table B.3**). With the optimal number of clusters defined a priori through the hierarchical clustering technique, at this point it was possible to apply the non-hierarchical clustering using the k-means algorithm to assign each observation to one of the clusters based on similarity. Specifically, the k-means algorithm partitions observations into clusters by minimizing the distance of individuals from one another within the same cluster and maximizing the distance of individuals between different clusters.

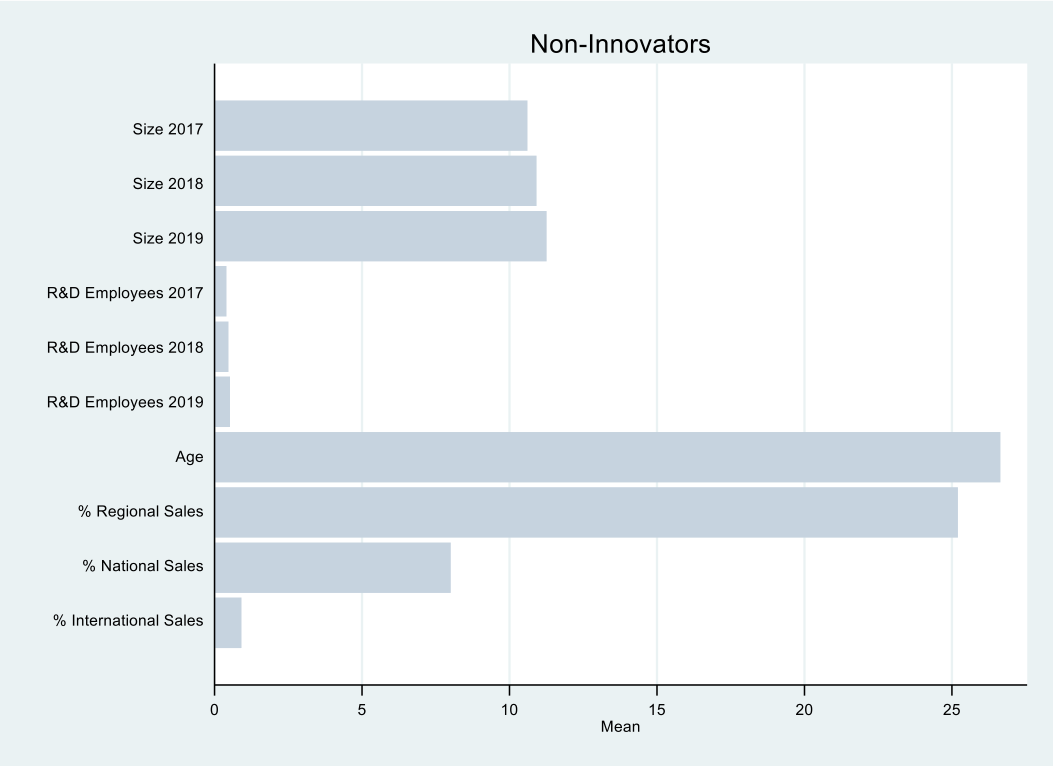
3.4 Results

3.4.1. Clusters' profiles

Fig 3.2-3.6 provide a description of the five cluster solutions to which it has been attributed a label. The next paragraphs will discuss the main features by combining demographical information with innovation adoption across different clusters.

Non-Innovators

Fig. 3.2 Non-Innovator cluster description



Product Design – Circular Innovation		6%		
Resource Efficiency – Circular Innovation		6%		
Clean Resources – Circular Innovation		5%		
Waste – Circular Innovation		9%		
Product Innovation		20%		
Process Innovation		23%		
R&D Investments		4%		
Green R&D Investments		1%		
Export		6%		
Agglomeration		17%		
Sector Technological Intensity	**Low**	**Medium-Low**	**Medium-High**	**High**
	37%	50%	12%	1%
N. Firms		895		

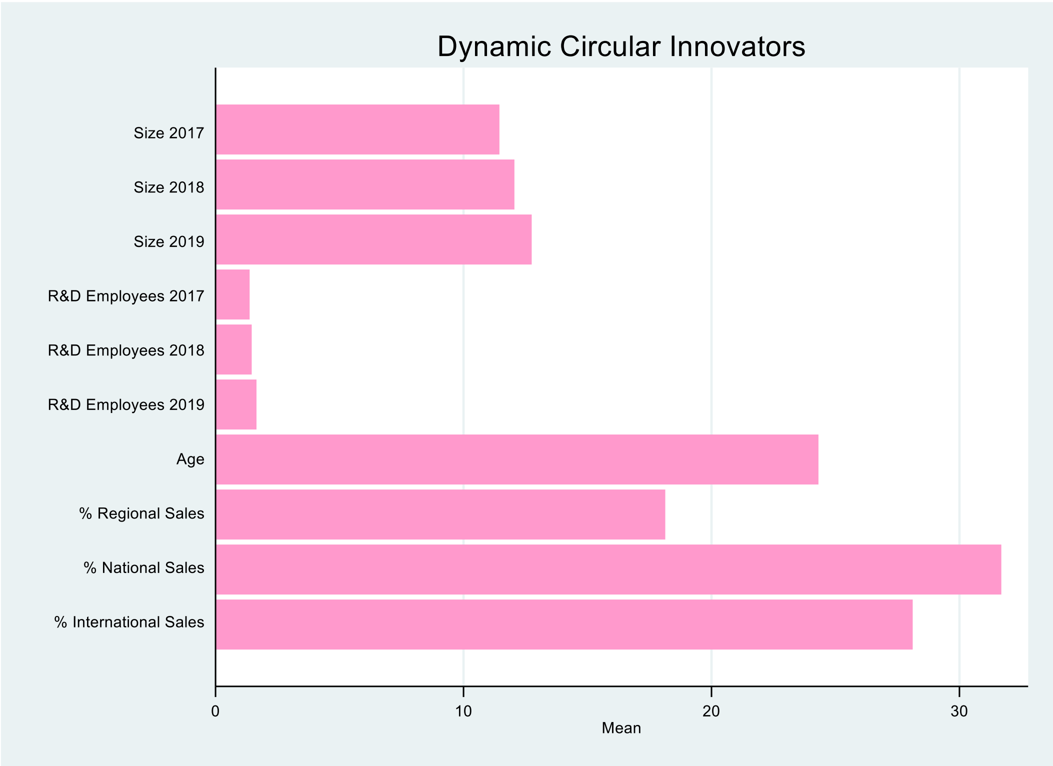
The *Non-Innovator* cluster represents the majority of firms operating across the CE region (895 observations). It is characterised by small and relatively young companies (27 years old on average), mainly operating in medium-low technology-intensive sectors and targeting a regional market[7]. Firms in this cluster show remarkably low levels of innovative activity.

[7] The sum of percentages between the different turnover distributions is less than 100, due to the lack of the share of local sales, which has been excluded from the analysis by the factor analysis procedure.

Accordingly, CI for product design has been adopted by 6% of firms, for RE and clean resources by 5%, and for waste management by 9% of firms, between 2017-2019. Slightly higher is the adoption rate of standard (product and process) innovation, which, however, does not exceed 23% of firms in the three-year period. In line with this, firms report low levels of investment in both R&D (4%) and green R&D (1%).

Dynamic Circular Innovators

Fig. 3.3 Dynamic Circular Innovators cluster description

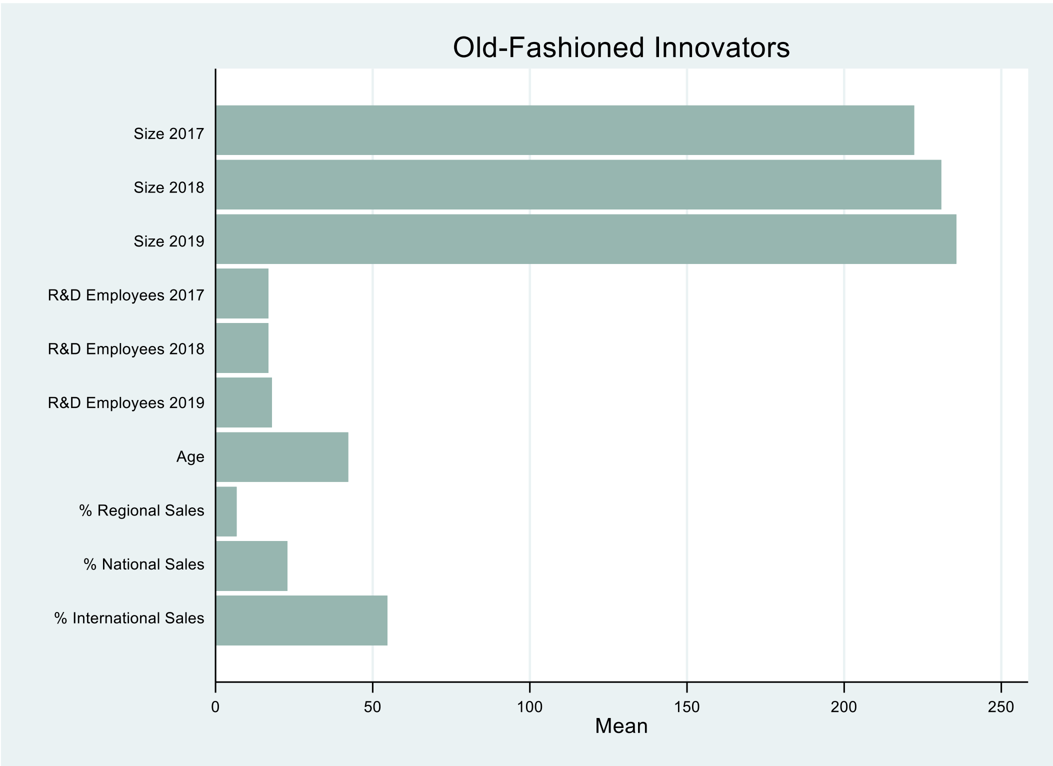


Product Design – Circular Innovation		100%		
Resource Efficiency – Circular Innovation		31%		
Clean Resources – Circular Innovation		47%		
Waste – Circular Innovation		63%		
Product Innovation		77%		
Process Innovation		66%		
R&D Investments		34%		
Green R&D Investments		15%		
Export		66%		
Agglomeration		20%		
Sector Technological Intensity	**Low**	**Medium-Low**	**Medium-High**	**High**
	24%	23%	46%	7%
N. Firms		96		

Differently from non-innovators, the combination between small size and young age seems not hindering the innovation capacity of *dynamic circular innovators* (representing 96 firms). These two characteristics, indeed, jointly with a strong propensity towards foreign markets (on average 28% of firms are oriented toward an international market, and 66% are exporting firms) and a medium-high technological intensity of sectors, probably foster more dynamism, enabling higher R&D investments (respectively 34% of firms invested in R&D and 15% in green R&D) and innovation rates. Notably, 77% of dynamic circular innovators have adopted product innovation and 66% process innovation, between 2017-2019. Additionally, in the same period, all firms have adopted product design CI, 63% CI on waste management, 47% clean resources CI, and 31% RE CI.

Old-Fashioned Innovators

Fig. 3.4 Old-fashioned Innovators cluster description

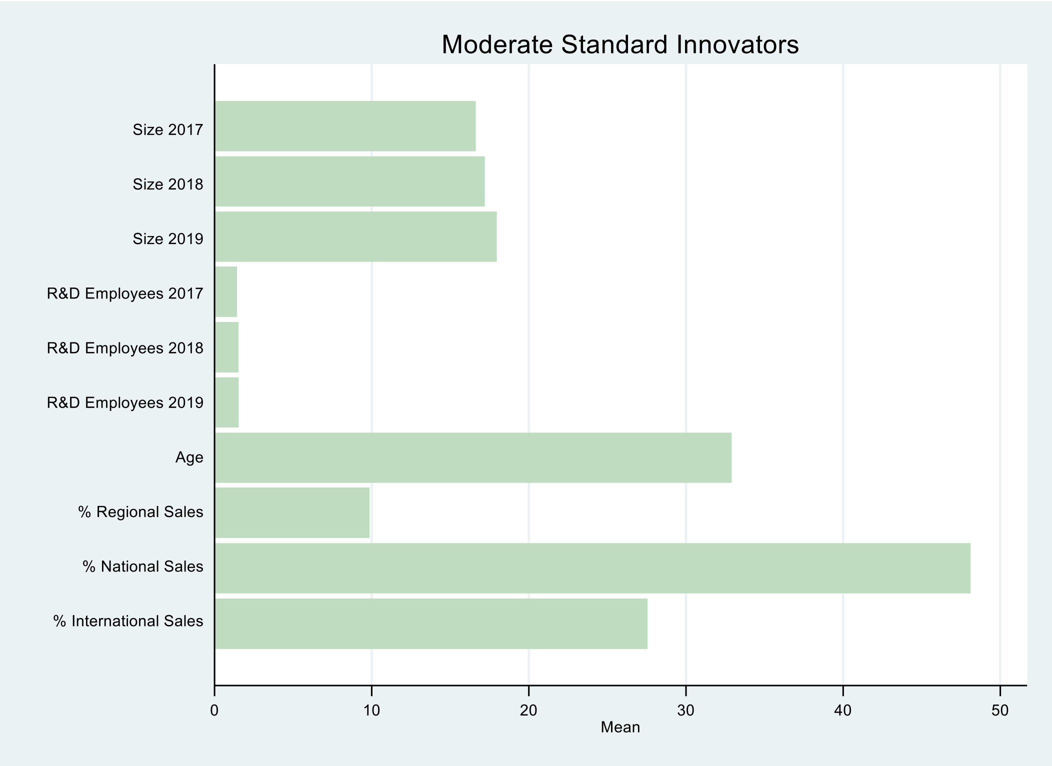


Product Design − Circular Innovation		36%		
Resource Efficiency − Circular Innovation		39%		
Clean Resources − Circular Innovation		11%		
Waste − Circular Innovation		50%		
Product Innovation		79%		
Process Innovation		57%		
R&D Investments		61%		
Green R&D Investments		25%		
Export		86%		
Agglomeration		36%		
Sector Technological Intensity	**Low**	**Medium-Low**	**Medium-High**	**High**
	25%	32%	36%	7%
N. Firms		28		

The *old-fashioned innovators* cluster collects 28 firms and it is made up of more experienced (average 42 years) and larger (average more than 200 employees) firms, operating in medium-high technological sectors, and whose turnover is split mainly between national and especially foreign markets. The 36 % of firms are part of a network, suggesting that their organisational structure may still reflect the traditional district form, typical of the CE industrial tissue. Firms belonging to this cluster seem to prefer the adoption of more standard types of innovation: 79% of them have introduced product innovation and 57% process innovation during the three-year period. Regarding CI, firms show high performance in terms of waste management innovation adoption, but the rate of the other CIs is rather low in comparison. This further reflects firms' preference for more classical forms of R&D investments. Indeed, while 61% of firms have invested in R&D between 2017-2019, only 25% have opted for green R&D investments.

Moderate-Standard Innovators

Fig. 3.5 Moderate Standard Innovators cluster description

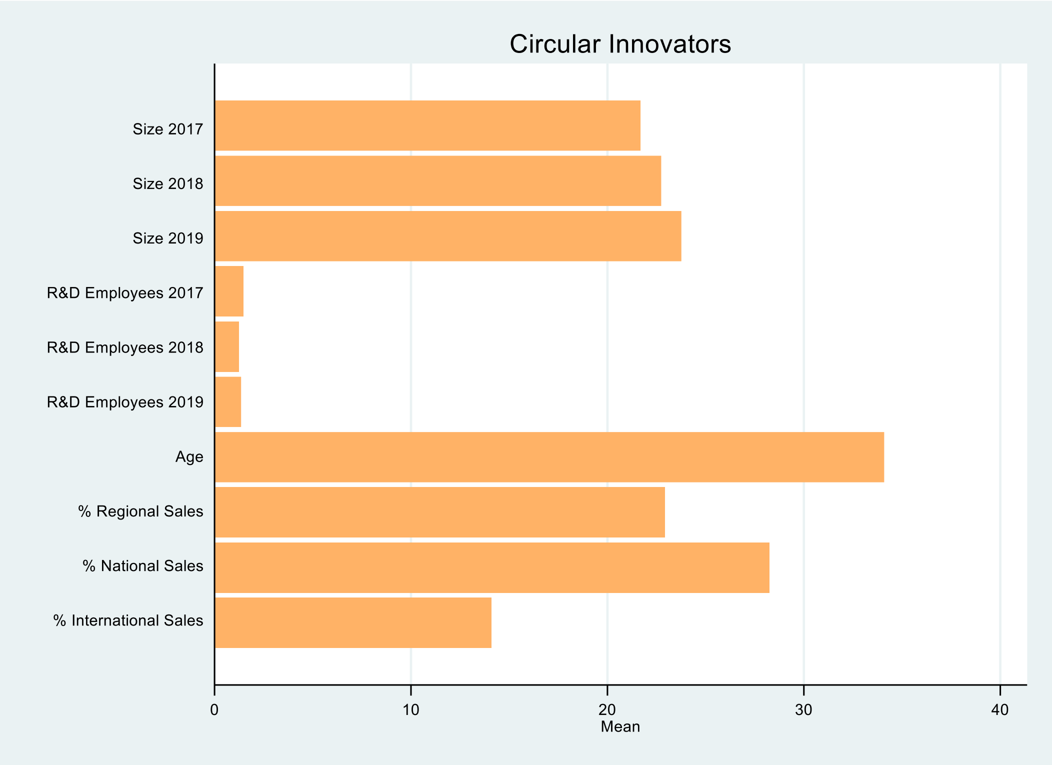


Product Design – Circular Innovation		13%		
Resource Efficiency – Circular Innovation		9%		
Clean Resources – Circular Innovation		8%		
Waste – Circular Innovation		18%		
Product Innovation		46%		
Process Innovation		37%		
R&D Investments		22%		
Green R&D Investments		5%		
Export		82%		
Agglomeration		13%		
Sector Technological Intensity	**Low**	**Medium-Low**	**Medium-High**	**High**
	31%	32%	34%	2%
N. Firms		431		

Moderate-Standard Innovators is a large cluster with 431 observations. It collects firms with around 20 employees on average, and 30 years of experience. Their turnover derives mainly from the national market (48%), although a good portion is also directed towards foreign markets (28%), with 82% of exporting firms. Firms in this cluster receive relatively little shelter from international openness. Generally, all clustering variables have moderate rates of both standard and CE adoption. In addition, the cluster shows a moderate propensity to invest in R&D (22% of firms declared having invested in R&D in the three years-period) and a low propensity to invest in green R&D (5% of firms).

Circular Innovators

Fig. 3.6 Circular Innovators cluster description



Product Design – Circular Innovation		25%		
Resource Efficiency – Circular Innovation		100%		
Clean Resources – Circular Innovation		22%		
Waste – Circular Innovation		68%		
Product Innovation		57%		
Process Innovation		62%		
R&D Investments		26%		
Green R&D Investments		8%		
Export		49%		
Agglomeration		27%		
Sector Technological Intensity	**Low**	**Medium-Low**	**Medium-High**	**High**
	29%	56%	12%	3%
N. Firms		114		

The cluster of *Circular Innovators* resembles those of moderate-standard innovators for dimension and age, but with two notable differences: a) their turnover is mainly internally distributed among the national and regional markets and b) firms report a significantly larger rate of innovation adoption. Interestingly, despite Circular Innovators seeming less oriented toward international markets, and despite their investments in both R&D and green R&D being rather low, they are vibrant innovators. 57% of firms have undertaken product innovation, while 62% process innovation. As for CI, the whole cluster has introduced CI linked to RE, and 68% waste management innovation. Membership of a network could be a determining factor in the innovative activity (17% of firms belong to an agglomeration) of these firms. For instance, with special regard to waste management, the existence of synergies among firms may be extremely relevant for the introduction of innovations aimed at by-products exchange.

3.5 Conclusions and Discussion

The EU is making unprecedented efforts to lead the industry towards a new circular *status quo*. Multiple studies have already demonstrated the beneficial effects of circularity on firms in terms of competitiveness, job creation, and resilience (Ghisellini et al., 2016 ; Moreno-Mondéjar et al., 2021 ; Horbach and Rammer, 2020). However, the literature is still scarce and many doubts remain, especially on how firms can effectively put in practice the objectives of CE. This study started with the question *What do circular innovator firms look like in ER?* The objective was to understand whether there are distinctive traits characterizing firms that decide and succeed in adopting innovative practices in the circular realm. This finally suggests which factors can facilitate and influence the decision of firms to assimilate strategies such as efficiency, reduction, recycling, and reuse within their business models. In nutshell, this can open the understanding on whom it can pay to go circular, in the specific territory of ER. Hereinafter a recap of the main findings.

First, the analysis highlights that R&D investments and the market scale mark the distinction between innovators and non-innovators. All innovative firms, regardless of their intensity level, declare to invest in R&D and are mainly oriented toward national and international markets. Differently, non-innovators, the majority of ER firms (895 non-innovators, 669 innovators) report low percentages of R&D investments and concentrate their business locally.

Second, between innovators, it seems to distinguish one cluster, the *old-fashioned innovators*, more prone to adopt standard innovation of product and process. These firms are characterized by a large dimension, a certain degree of experience (the mean age is indeed 42 years), and a business directed toward international markets.

Third, it emerges that CI is largely implemented by those firms that in this study are recognized within the *Dynamic Circular Innovators* cluster. Therefore, small and young companies, which nonetheless exploit these characteristics as a source of dynamism rather than an obstacle, as demonstrated by their vitality in domestic and foreign markets.

Taken together these findings highlight, the importance of knowledge and research to build competencies and openness toward innovation. Accordingly, a large consensus has already been provided by the literature on EI on the role of R&D to foster EI adoption (Horbach, 2008; Horbach et al., 2012). Furthermore, De Jesus and Mendonça (2018) have suggested that increasing the capital knowledge of firms is an important condition for CE. Despite this, in the specific realm of CI, there are mixed results on the relation between CI and R&D as reported in Cainelli et al., (2020).

Nevertheless, at least in the case of ER, R&D investments seem to be a necessary but not sufficient condition to open the horizons of traditional businesses towards circularity. There is a need for young and flexible firms oriented toward international markets. This result places the discussion within another widely studied strand of the literature, that link export propensity with innovation adoption, in its traditional definition. On the one hand, empirical evidence has demonstrated the effect of *learning by exporting* (Love and Ganotakis, 2013). Knowledge flows deriving from foreign sources can indeed offer an opportunity for exporting firms to improve their innovative performances (Clerides et al, 1998). On the other hand, other studies have shown the positive impacts of innovation (of product or process or combined) adoption on export propensity. For example, improving technical efficiency through process innovation can reflect in costs reduction, hence firms «can charge lower and more competitive prices in foreign markets and expect higher profits from exports, which in turn increase their probability of exporting» (Bernardini Papalia et al., 2017, p. 4). Besides the determination of the causality between export and innovation adoption, which is beyond the scope of this study, what is relevant to note is the existence of a link between the two factors and in the specific case of CI.

These results can give rise to various interpretations. One could be faced with newly-born companies, which already start with the idea of placing the CE at the centre of their business, or young firms, therefore, possessing such flexibility as to allow an easier propensity and adaptability to the new organisational schemes, or again firms *of* young people who have therefore grown up in an era in which the sensitivity to environmental protection issues has become stronger.

These findings can find justification in the nature of CI. As already discussed in Ch. 1 incremental EIs act in support of more radical modifications. Therefore, often the implementation of similarly incremental practices such as recycling, reuse, and efficiency may require more complex organisational innovative process, hence the reorganization of entire settings of production. It follows that despite large and experienced companies should have the financial capabilities to innovate, still, the costs of adopting such changes may result higher than the benefits. Instead, the most advantaged companies seem to be either those who set a CBM from the beginning, or those who have the flexibility, competence, and capacity to adapt to the change. From here some insights can be drawn for the development of future regional policies. Supporting companies with targeted plans to facilitate innovation processes and R&D investments (e.g. the recent Transition 4.0 plan) may be not sufficient. This analysis has indeed brought to light at least other three aspects to consider: flexibility, internationalization and culture, as key to successfully leading the implementation of CI among firms in ER.

For further research exploring the mechanisms that influence and determine firms' strategies is of paramount importance. To this end, it would be appropriate to study the trajectories and dynamics of circular-oriented innovation diffusion. For this purpose, building on the cluster analysis research, the use of differential equation systems would allow to shed light onto the processes of diffusion and growth of new technologies, taking into account not only economic but also geographical and social variables. Specifically, the study will focus on whether the adoption of circular innovation by firms is determined by a contagion effect, and how this contagion spreads following specific firms features.

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Appendix B

Table B.1 Descriptive statistics of variables used for the elaboration of the factor analysis

Variable	Description	N. Obs.	Mean	SD	Min	Max
SUPPLCHAIN	Membership of the company in a production chain	1.598	.1627034	.3692104	0	1
DISTR	Membership of the company in an industrial district	1.598	.0212766	.1443501	0	1
EXP	Exporting firm (2017-2019)	1.598	.3548185	.4786081	0	1
SIZE17	Firm dimension 2017	1.598	1.743.492	3.587.197	0	580
SIZE18	Firm dimension 2018	1.598	1.806.508	3.697.481	0	545
SIZE19	Firm dimension 2019	1.598	1.870.401	3.867.145	0	520
REDEMPLOY17	Number of R&D employees with university degree 2017	1.598	1.134.543	3.817.705	0	62
REDEMPLOY18	Number of R&D employees with university degree 2018	1.598	120.776	3.830.065	0	53
REDEMPLOY19	Number of R&D employees with university degree 2019	1.598	1.282.228	4.048.216	0	50
PRODINNO	Introduction of Product Innovation (2017-2019)	1.598	.3441802	.4752489	0	1
PROCINNO	Introduction of Process Innovation (2017-2019)	1.598	.330413	.4705091	0	1
TechObstacles	Presence of technical obstacles during the adoption of product/process innovation	1.598	.1846058	.3880989	0	1
AdministObstacles	Presence of administrative obstacles during the adoption of product/process innovation	1.598	.1520651	.3591964	0	1
LegalObstacles	Presence of legal obstacles during the adoption of product/process innovation	1.598	.0763454	.2656331	0	1
MarketObstacles	Presence of market obstacles during the adoption of product/process innovation	1.598	.1289111	.3352065	0	1
RED	Investments in Research and Development (2017-2019)	1.598	.1414268	.3485703	0	
GREENRED	Investments in Research and Development to reduce the environemental impacts of production (2017-2019)	1.598	.0394243	.1946631	0	1
INDUSTRY40	Introduction of technological innovations using the Program Industry 4.0	1.598	.1664581	.3726079	0	1
WATER	Adotion of innovation to reduce water consumption (2017-2019)	1.598	.0413016	.1990492	0	1
RAWMAT	Adoption of innovation to reduce resources consumption (2017-2019)	1.598	.1307885	.3372744	0	1
DESIGNRE	Adoption of innovation aimed at changing design to reduce material use (2017-2019)	1.598	.0769712	.2666292	0	1
RENEW	Adoption of innovation to use renewable energy (2017-2019)	1.598	.0494368	.2168461	0	1
DENERGY	Adoption of innovation to reduce energy consumption (2017-2019)	1.598	.0569462	.2318123	0	1
DURABILITY	Adoption of innovation aimed at changing design to favour durability (2017-2019)	1.598	.0788486	.2695866	0	1
DISASSEMBLY	Adoption of innovation aimed at changing design to favour disassembly (2017-2019)	1.598	.0369212	.1886273	0	1

REPAIR	Adoption of innovation aimed at changing design to favour repair (2017-2019)	1.598	.068836	.2532544	0	1
DESRECYCL	Adoption of innovation aimed at changing design to favour recyclability (2017-2019)	1.598	.048811	.2155402	0	1
BIOMAT	Adoption of innovation to substitute materials with high environmental impacts with sustainable materials (2017-2019)	1.598	.0738423	.2615959	0	1
REDWASTE	Adoption of innovation to reduce waste generation per output produced (2017-2019)	1.598	.0882353	.2837256	0	1
REUSEWASTE	Adoption of innovation to reuse waste within own productive process (2017-2019)	1.598	.043179	.2033234	0	1
DELIVWASTE	Adoption of innovation to exchange waste with other firms (2017-2019)	1.598	.0669587	.2500287	0	1
Internal Resources	Instruments to finance the adoption of Circular innovation	1.598	.2390488	.4266361	0	1
Bank Loans	Instruments to finance the adoption of Circular innovation	1.598	.0581977	.2341903	0	1
Green Bank loans	Instruments to finance the adoption of Circular innovation	1.598	.0025031	.0499843	0	1
Public Subsidies	Instruments to finance the adoption of Circular innovation	1.598	.0125156	.1112059	0	1
AGE	Firm age	1.598	2.893.242	1.886.509	1	193
ETS	Knowledge of the price of a ton of CO_2 in the ETS (2019)	1.598	.0569462	.2318123	0	1
COVIDIMPACT	Turnover impact of Covid-19 crisis outbreak	1.598	15.801	.645415	1	4
TECH	Technological intensity of the sector	1.564	1.913.043	.7910948	1	4
REGTURN	% of Regional turnover	1.598	2.012.015	2.813.612	0	100
NAZTURN	% of National turnover	1.598	2.230.225	2.937.409	0	100
EXTTURN	% of International turnover	1.598	1.201.877	2.388.164	0	100

Table B.2 Barlett test of sphericity

Bartlett test of sphericity	
Chi square	31.580.945
Degrees of freedom	861
p-value	0.000
H0: variables are not intercorrelated	
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	
KMO	0.815

Table B.3 Stopping rules for hierarchical clustering

N. of clusters	Chalinski-Harabasz pseudo F statistic	Je(2)/Je(1)	Pseudo T squared
3	56.13	0.9604	63.90
4	59.96	0.9609	62.50
5	61.92	0.7108	5.29
6	51.84	0.9552	71.32
7	56.57	0.9789	32.15
8	53.79	0.9629	57.17
9	55.39	0.6868	2.28

In absence of a conclusive test to identify the right number of cluster to retain, there are several rules of thumb based on a series of statistical tests, e.g. Pseudo T-squared statistics, Je(2)/Je(1) statistics and Chalinski-Harabasz pseudo F statistics, which indicates how distinct cluster solutions are. Clusters should indeed be characterized by high heterogeneity from one another, and display similarity between observations belonging to the same cluster. The number of cluster to select should be a) in accordance to the Chalinski-Harabasz pseudo F statistic the largest value across the different options (in this study, five), b) in accordance to the Je(2)/Je(1) statistic the large and a local maximum value (in this study, seven), and c) in accordance to the Pseudo T-squared is the local minimum value (in this study five, excluding a priori the nine cluster solution). Therefore, two test out of three suggest the five cluster as the optimal solution to select, hence the one with the most heterogeneous clusters.

Concluding remarks

This thesis represents the attempt to shed more light on two issues regarding the operationalization of CE at the firm level, namely 1) Which CBMs emerge from the adoption of CIs? and 2) which are the drivers that favour the implementation of CIs? The three chapters theoretically and empirically discuss these questions. Hereinafter is a brief recap of the main findings.

The first chapter encompasses the literature on the definition of CE and EI in order to examine the common grounds between the two concepts and provide a definition for CIs. This excursus led to defining CIs according to de Jesus et al., 2019: «transformative" pro-CE innovation is thus a Schumpeterian new combinations of "harder" (R&D-driven products, cost-cutting processes, technical solutions embedded in cleaner products and processes) and "softer" types of knowledge (the institutional setups, BMs and the behavioural patterns inscribed in circular organisational and marketing solutions)» (de Jesus et al., 2019, p. 1496). Relying on this theoretical architecture, the study has subsequently identified a series of circular practices that firms should implement in order to undertake changes in the way they create value. Three different categories of CBMs emerge according to the Product Life-Cycle Archetype: BMs based on circular input, BMs based on circular use, and BMs based on circular output.

The second chapter proceeds from the behavioural economics concepts of social norm and peer effect in order to find evidence of a causal relationship between peers' behaviour and firms' decision to introduce CI. The analysis has been developed on a sample of 3270 Italian manufacturing firms. The results reveal that believing that firms' peers are increasing investment in CIs increases the likelihood that firms will actually introduce the same innovations. This signals the existence of a social norm imitation mechanism, usually demonstrated among consumers, also among companies. Alongside traditional market levers, CI could therefore be driven by information nudges that make firms aware of the most common behaviour of their peers.

The third chapter considered the case study of the ER region in order to take a closer look at the characteristics of firms that excelled in adopting CIs. The cluster analysis showed that R&D investments mark the boundary between innovators and non-innovators, confirming a broad strand of literature on the topic. Moreover, small and young firms are the ones that showed a higher propensity to adopt CI.

Acknowledgments

This thesis marks the end of an important journey and represents therefore the opportunity to take a pause and look at the end aware of the starting point. After graduation I did not know what was my place in the job market and I believed I did not possess the necessary skills to deserve one. Even today, I still can't say what my role will be, but the most important thing I have learned is that I do not always have to feel capable and competent in order to be able to undertake a task. I was lucky enough to work in the research group led by Prof. Massimiliano Mazzanti, whom I thank first and foremost for giving me the opportunity to go beyond research and acquire more skills than a traditional Ph.D. offers. It was mainly from him that I tried to learn to throw myself into the 'new' and to face situations I did not think I could handle. None of this, however, would ever have been possible without Prof. Susanna Mancinelli and Prof. Stefania Ragni, the first two people who gave me trust without knowing me and who chose me among the other candidates; to them goes my heartfelt thanks. Prof. Susanna Mancinelli guided me along the Ph.D. while leaving me the freedom to trace my own route. She protected me with her experience, she opened my eyes with her advices and knowledge, she gave me passion, she made me brave, she made me laugh, she amazed me with her simplicity, she was simply Susanna and I hope I managed to deserve the trust she always placed in me. Emy and Chiara were colleagues and friends, Emy taught me to never focus on the hurdles but on the way to overcome them, Chiara passed down to me kindness, precision, sensitivity and organisation. Ilaria my explosive and overwhelming travelling companion was the ear that listened to my insecurities and weaknesses, but also the source of so much fun and laughter.

I would also like to thank Prof. Davide Antonioli and Prof. Francesco Nicolli for having supported and followed the drafting of the thesis, especially the econometric part, and Dr. Marco Quatrosi for having guided me through the cluster analysis, and thanks to Prof. Stefania Ragni for having brought me closer to the dark science that mathematic is for me. Thanks to Prof. Phoebe Koundouri for giving me the opportunity to collaborate with her Greek research team, in particular with Angelos Plataniotis and Stathis Devves. Thank you to Prof. George Halkos because it was an honour to work closely with him and to have acquired new skills from him, thank you also for never letting me lack a smile. Many thanks to my two reviewers: Prof. Florian Flachenecker and Prof. George Halkos who dedicated themselves to reading my work and helped to enrich and improve it with their comments.

All these people and the many others I have met over the past three years have contributed to triggering in me the desire to always give my best, from each of them I have tried to learn and take what I have seen to be their best in order to build and enrich my professional (and not only) figure.