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Orchestrating entrepreneurial ecosystems in circular economy: the new paradigm of sustainable competitiveness

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Abstract

Purpose – The Paris agreement for climate changes brought new attention to the themes of reduce carbon emissions, green ecosystems, the circular economy and the need to ensure the emergence of sustainable entrepreneurial ecosystems. This study aims to investigate entrepreneurship from the perspective of circular economy and waste collection in the Portuguese context.

Design/methodology/approach – Following a quantitative approach, the sample comprises 2,690 firm-year observations related to 354 firms from different industries within the waste from electric and electronic equipment (WEEE) scope.

Findings – The results show that a large part of SMEs started to comply with waste management regulations as of 2006 and are still not prone to innovation. Regulatory compliance is expected to have a positive impact on innovation, with a significant and positive change in the number of patents and the value of intangibles after companies comply with the waste management regulation.

Originality/value – This paper is original because it addresses equally to entrepreneurial ecosystems and circular economy (studies that address these two aspects are rare), with the Portuguese context in an embryonic stage with an extensive path to follow in the applicability of circular economy to business.

Keywords Entrepreneurial ecosystems, Circular economy, Triple bottom line, Triple helix, Innovation

Paper type Research paper

1. Introduction

Research and innovation strategies for smart specialization (RIS3), emerged from the perceptions about regional innovation systems for economic development, and were

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implemented in 2014 in the European Union (EU) (Lopes *et al.*, 2019b). RIS3 focuses on a "business discovery" approach to identify opportunities for regional economic development (Hausmann and Rodrik, 2003; Vidmar, 2019). Thus, the regions had to define the smart specialization domains where the investment needed to focus, in order to increase the competitiveness of the regions (Lopes *et al.*, 2019b; Kroll, 2015; Boschma, 2014).

In this context, for the 2014–2020 period there has been an EU effort to reduce carbon emissions. This effort will be reinforced in the next 2021–2027 period as an attempt to make the EU increasingly greener with substantial reduction on the carbon emissions, with the RIS3 of some regions being subject to adjustments. These premises were approved in the Paris agreement for climate changes, where investments in energy transition to combat climate change and energy from renewable sources were agreed (Călin and Antoneac, 2020; Bilas, 2020). As such, the EU is directing its objectives on innovation and financing structural funds for innovation policies based on the challenges associated with sustainability (Jutting, 2020).

Entrepreneurial ecosystems are relevant to the economic policies of a substantial number of countries, and especially the ones in Europe. The entrepreneurial ecosystems concept offers a new perspective on the geographical clustering of economic activity. Alongside with regional development strategies policies in Europe (EU), and supported by a continuous technological evolution, entrepreneurship and ecosystems are matters that have stimulated researcher' interest (Lopes *et al.*, 2019b; Fernandes and Ferreira, 2021).

Being so, it is important to establish a relationship between the entrepreneurial ecosystems and the daily ecological praxis within societies. This can be achieved through global and regional environmental initiatives aiming to recognize the importance of waste management, recycling, reuse and sustainable development (Hsieh *et al.*, 2017). These initiatives fall into a new broad scope known as circular economy, whereby the moto "take, make and dispose" (Ness, 2008) which has driven societies throughout the last three centuries is replaced by a new vision known as "make, use, recycle."

Circular economy consists on materials assessment within a closed system, with the aim to reduce the use of natural resources, thereby reducing pollution, or impose restrictions on resources usage, thus increasing sustainable economic growth (Winans *et al.*, 2017). Circular economy has the premise of providing a better alternative to the predominant linear economic model of "make, take and dispose," leading to a more sustainable development of symbiotic entrepreneurial ecosystems (Ness, 2008; Hsieh *et al.*, 2017).

According to Neumeyer *et al.* (2020), entrepreneurship is little explored from the perspective of the circular economy for three reasons: (1) education for current entrepreneurship is still mostly concerned with modeling linear ventures. Alternatives to this more conventional path are beginning to emerge, for example, the "Triple Layered Business Model Canvas" model developed by Joyce and Paquin (2016). The "Triple Layered Business Model Canvas" model addresses to the innovation of the business model from the perspective of sustainability. This new model includes three layers (economic, environmental and social), that is, it adds two new layers, in detriment of the traditional model that only uses one (economic) (Joyce and Paquin, 2016); (2) although academic entrepreneurship programs are receptive to adopt concepts such as the circular economy and sustainability, they are not provided with the essential knowledge on waste and resource management processes, as well as existing technology, such as information technologies, ecological feedback, zero waste or recycling manufacturing and recovery technologies; (3) instructional media, such as textbooks, approaches sustainability as a disaggregated area of economy; thus, the efforts to insist on a circular view in entrepreneurship will become an utopia (Neumeyer *et al.*, 2020).

Another reason to explore circularity and sustainable entrepreneurship is related to the fact that, to date, there is no notable growth and significant impacts in this area, furthermore, lacking the socioeconomic and demographic diversity. Policymakers have been given preference to provide incentives for the creation of high-tech, fast-growing start-ups. These start-ups are mostly founded by men, marginalizing women, who are seen as minority entrepreneurs and with low income (Neumeyer and Santos, 2018). However, investing in sustainable and enterprising entrepreneurial activities can help entrepreneurs in low-income environments to produce/create increasingly innovative services and products, thus finding segments of customers with greater financial capacity and less sensitivity to price, thus protecting itself from the "commodity trap" (Morris *et al.*, 2020; Cerver Romero *et al.*, 2020).

Current researches are focused on how companies can benefit from the ecosystem network, in order to achieve higher commercial performance (de Lima *et al.*, 2019). However, only a small amount of research has addressed how start-ups or companies can adapt/shape the entrepreneurial ecosystems in which they operate, in order to simultaneously achieve business and environmental objectives, thus making ecosystems more sustainable and greener (Hsieh *et al.*, 2017). However, only a small part of research was focused on how the operations of a business ecosystem could have a positive impact on our environment (overall sustainability).

The objective of this paper is to investigate entrepreneurship from the perspective of circular economy and waste collection within the scope of waste from electric and electronic equipment (WEEE) in the Portuguese context. With this study, we intend to assess on how entrepreneurship in the circular economy can be improved, leaving recommendations to policy makers, academia and entrepreneurs. We aim to contribute to the development of an increasingly green and sustainable economy. This paper is original because it addresses equally to entrepreneurial ecosystems and circular economy (studies that address these two aspects are rare), with the Portuguese context in an embryonic stage with an extensive path to follow in the applicability of circular economy to business.

This paper is organized as follows: In the first part there is an introduction, where an extensive overview on the theme under study is carried out. In the second part, a broad literature review on entrepreneurial ecosystems and circular economy is portrayed. In the third part, the methodology used is described. In fourth part, results and discussion of results are presented. Finally, a conclusion is elaborated, indicating the practical implications, limitations of the research and future lines of investigation.

2. Literature review

Nowadays, entrepreneurial ecosystems are relevant to the economic policies of a substantial number of countries, especially the ones in Europe. Entrepreneurial ecosystems influence the environment and institutions, and is indispensable to encourage new enterprises that will generate economic wealth and new jobs (Jutting, 2020), this concept is mainly focused on:

(1) The entrepreneurial activity, start-up success and wealth creation;

(2) The necessary support structures and intermediaries to encourage new ventures.

The concept of ecosystem provides a systemic manner to portray social systems through a business ecosystem (Moore, 1993), innovation and entrepreneurial ecosystem (Farinha *et al.*, 2020).

Previous research was focused on how entrepreneurs could go through a self-regulatory process and successfully manage challenges in an ecosystem (Nambisan and Baron, 2013; Lopes *et al.*, 2019a). Actual academic research on business ecosystem has a holistic approach on several areas of knowledge such as strategic management, innovation, operations management, and others. Nevertheless, most of the current research is focused on the economic value created by the business ecosystem (Hsieh *et al.*, 2017).

Being so, there is an opportunity and necessity to develop a new stream of business ecosystem research linked to sustainability and adjacent areas such as circular economy, thus, contributing to the knowledge of how a leading firm might lead a good and sustainable ecosystem, in order to simultaneously maintain the business and environmental values (Gregson *et al.*, 2015). Nonetheless, while the discourse on innovation ecosystems has grown significantly over the last years, today's main quests on sustainability are yet to be attained (Liu and Stephens, 2019).

On the actual environment, a substantial number of challenges arose, which cannot be accomplished by one actor only, being it from politics, science or industry. An appropriate analytical framework to analyze the processes of collaborative innovation is missing (Jutting, 2020). The literature highlights the importance of governments, as regulators. In some cases, civil society organizations or NGOs, may act as alleged environmental leaders (Fliaster and Kolloch, 2017). Governmental institutions may also have an impact on how firms govern their ecosystem, when they introduce or modify rules and legislation.

The implications of an entrepreneurial ecosystem may lead to a dual outcome: First, the efforts to encourage a relevant entrepreneurship growth cannot be restricted to top-down efforts that are merely focused on the framework conditions. Bottom-up efforts, containing other tiers of government as well as non-government actors, are also required. Second, it needs a distinctive set of policies from those that are targeted at business start-up in general. Just focusing the policy efforts on the increment of new businesses may have little effect, because only few firms achieve a significant growth (Mason and Brown, 2014).

The business ecosystem granted a new paradigm for management research, whereby most research in the field was focused on profit-driven industries, neglecting areas of sustainability (Hsieh *et al.*, 2017), and green transition ecosystems.

Green ecosystems can be defined as innovation ecosystems, aiming to achieve environmental sustainability, through the transformation of the underlying patterns of production and resource use, and a strong focus on environmental sustainability (Jutting, 2020). According to Yarahmadi and Higgins (2012) these ecosystems aim to leverage external competences on one hand, whilst complying with environmental regulations on the other, to obtain legitimacy. Nurturing green innovation ecosystems will conduce firms to a circular economy approach, thus, they may be considered as ecosystem leaders and primary solution drivers. Furthermore, once combined with citizens in the community, it may generate recycling funds to assure that waste is recycled and reused, thus, ensuring the necessary steps for transition to a circular economy.

Actual literature on circular economy indicates that its appearance is related to the exhaustion of the linear economy model also known as "take, make and dispose" (Ness, 2008). The linear economy is based on a simple process: extracting, producing and consuming, with little attention to the pollution generated at each stage of the process, being primarily characterized by economic objectives, with less attention to ecological and social issues as well as loyalty among the inherent political and public interventions.

According to the European Environment Agency (2016), the older linear economy is an open economic model based on three basic factors: (1) cost of restructuring, (2) standard assets, which leads to (3) winners and losers. On the other hand, circular economy is a continuous economic model centered on: (1) economic benefits, (2) environmental benefits, (3) resources benefits, and (4) social benefits. This model increases the awareness on finite planet resources, reduces its consumption, increases the communication between producers and consumers, and prevents pollution.

Transition to a circular economy can be achieved through multiple forms, for example, setting up infrastructures to collect and separate municipal and industrial waste, renewable energy, biorefinery, remanufacturing and sustainable mobility (Barrie *et al.*, 2017). This new concept, also regarded as "make, use, recycle" has flourished in the recent years covering the ideas of industrial symbiosis, extended product life (Gregson *et al.*, 2015), impacts of climate change, rapid urbanization, demographic developments, and a dynamic shift in demand patterns (Gruchmann *et al.*, 2018).

Moreover, all the transformations on the manufacturing operations, delivery processes, and waste management of companies will become important factors in the future of consumer's purchasing decision. As a visible effect, the industry, governments and scholars are paying more attention to this area, thus, embracing the idea of the green economy (Hsieh *et al.*, 2017). The environmental consequences of a continuously economic growth led the industry, academia and politicians to debate a transition to a "green economy" and a complete change in the paradigm of growth and development, which led to new notions of orientation to sustainability (Dacko *et al.*, 2013), and the reduction on the intensity of resources exploration intensity and processes of dematerialization.

With the unescapably necessity to save energy and reduce the usage of natural resources, a new type of economy based on sustainable models is needed in the industry. Several concepts, along with their different terminologies have emerged. Two of the most common are "environmental sciences "and "sustainable development," more recently the term "Circular Economy" (CE) came into circulation (Sauve *et al.*, 2016).

Moving to a circular economy concept requires the integration of different stages in the life cycle, one example would be designing products from the outset for easy recyclability (Nielsen *et al.*, 2020).

Florin *et al.* (2015) identified five main reasons to move to a circular economy:

(1) Substitute renewable energy and material inputs;

(2) Create wealth from waste;

(3) Adopt a stewardship role;

(4) Maximize material and energy productivity; and

(5) Deliver functionality rather than ownership.

A considerable number of sectors already identified the "create wealth from waste" epitome as the most prevalent and the one to be considered as an indicator on where new value opportunities will arise and help to rethink on how we currently value waste and will embrace new modes of consumption. Therefore, it can be considered that the transition to a circular economy is not just a set of adjustments aimed to reduce the negative impacts of the linear economy. On the contrary, it represents a systemic change that creates long-term resilience, generates commercial and economic opportunities, and provides environmental and social benefits (Gregson *et al.*, 2015).

Lately, circular economy is receiving increasing attention as a way to overcome the current production and a consumption model based on continuous growth and new resources utilization. While in some sectors the implementation of circular economy is still at an early stage of development, it already offers a reliable framework to improve the present business model towards preventive and regenerative eco-industrial development as well as increased wellbeing based on recovered environmental uprightness (Ghisellini *et al.*, 2016).

On the extensive analysis of literature, circular economy (CE) concept shows to be rooted in very diverse theoretical backgrounds: ecological economics, environmental economics and industrial ecology (Ghisellini *et al.*, 2016). Despite some limitations, primarily due to physical constraints, circular economy seeks to continually sustain the circulation of recovered resources and energy within a closed system (the planet) thus reducing the need to feed production systems with new raw materials (Genovese *et al.*, 2017).

In this context, we can establish a circular economy loop embracing its key areas of intervention:

(1) Retailers: Those who perform all the activities related to the original product (including marketing and distribution);

(2) Consumers: Customers that use the original product and forward the non-used part of the product to the collecting or recovering systems;

(3) Material Recovery: Physical collection and processing and transferring;

(4) End user: Parts usage, recycling or re-manufacturing.

Some industrial ecology is rooted in this process to provide a conceptual model for the industrial development, based on improving the material interactions between firms, within a certain geographical distribution or industrial cluster (Ferrão *et al.*, 2016). Companies and consumers are reducing substantially the linear model and adopting a value creation model that begins with extraction and concludes with disposal for recovering, much of the recent interest in sustainable waste management derives from the context of implementing a circular economy. Resources are acquired, processed using energy and labor, and sold as reusable goods with the expectation that customers will discard those goods and buy more (Ruiz-Real *et al.*, 2018; Zucchella, 2019; Bouton *et al.*, 2016).

Specific circumstances such as regulations and motivations have stimulated circularity ideas such as reuse, remanufacturing or recycling, thus, the environmental impacts are increased pressure on industrial businesses (Lieder and Rashid, 2016). One of the waste regulations now on in force in the EU countries is related to the Waste Electrical & Electronic Equipment also known by WEEE (Commission Decision 2004/249/EC). Constructs like sustainability, extended producer responsibility, circular economy, waste management and product environmental footprint are on the root of this type of legislation (Klitkou *et al.*, 2019).

Within the WEEE directive, waste from consumer's electrical goods containing various metals difficult and expensive to procure, can now be easily obtained from the diverse components of this type of products, thus, incrementing circularity and reducing the possibility of landfill as a final destination. The WEEE directive has been evolving since its introduction 2003 and started with a recovery target of 4kg/inhabitant/year to the actual 65% of recovery of the weight placed new in the market.

Waste can be impressive due to its inextricable mix of social, economic, and environmental attributes. The increased production of solid waste due to globalization, the rapid urbanization coupled with industrialization is threatening the human health and the environment (Singh *et al.*, 2011). Furthermore, waste can be distressing due to the limits of its problem definition, which is focused on the environment and resources. This limitation of problem definition may lead to conflicting values on waste and recycling between various involved stakeholders. In developed countries, waste management system, is highly dependent on capital and intensive technical solutions with public expenditures (Tong and Tao, 2016) or legislation applied fees.

Turning waste into a resource, requires going beyond fees and weight charge. It requires that waste is turned into commodities, bought and sold in markets. Discarded goods, objects or materials, requires proper separation and segregation, sorting, and sometimes treatment, to be rendered as tradable commodities suitable for purchasing by manufacturers (Gregson *et al.*, 2015). EU plans refer to the need of a high-quality infrastructure in the various countries, whose performance is beyond collection targets in some geographical areas; this will imply a change in mindset, facing resistance to change and inevitable costs to the stakeholders, on the other hand, it will address the necessary environmental and socio-economic issues in the long term aiming the wellbeing of actual and futures generations.

Moreover, circular economy aims to transform waste into future resources and leverage production and consumption activities (Witjes and Lozano, 2016), this implies creating an economy where the outputs from one value chain are used as inputs in another chain (Klitkou *et al.*, 2019), thus, providing a sustainable footpath to economic growth, while decreasing the inputs of materials and waste, necessary to reduce such streams in cities (Savini, 2019).

With the introduction of the WEEE directive, management entities were created in all member states to undertake the responsibility of WEEE collection, disposal and reuse of the components from electric and electronic products. In Portugal, the created management entities are obliged to perform the tasks transposed from the Commission Decision 2004/249/EC on a countrywide coverage (including the islands).

As for the entrepreneurial business ecosystems this is important for the following reasons:

(1) Compliance with environmental regulation;

(2) Firms will create an image of sustainability and care for the environment;

(3) Innovation growth after the implementation of the Commission Decision 2004/249/EC;

(4) By nurturing a green and a circular economy approach, firms are considered as ecosystem leaders and will play an important factor in the future of consumer's purchasing decision.

Taking into account the actual literature review and the state of the art, the following research hypothesis is proposed:

RH1. Are firms that comply with WEEE regulation more innovative?

To test our research hypothesis, we follow previous literature (e.g., Faurel *et al.*, 2017; Potepa and Welch, 2017) and use alternative proxies to capture the value of innovation, namely, the number of patents and the value of intangibles. It is widely recognized in prior literature that the research and development (R&D) output is (roughly) measured by the number of patents and copyrights, which represent the most considerable contribution to intangibles' value (Lev and Sougiannis, 1996). Therefore, we aim to examine if regulation enhances the firms' ability to be more innovative, although controlling for firm attributes widespread in former studies that can impact the outcome of innovation activities such as size (Kim *et al.*, 2009), profitability (Ericson, 1995), leverage (Hall and Lerner, 2010), sales growth (Loureiro and Silva, 2020) and investment in fixed assets (Ferrer *et al.*, 2020).

3. Methodology

3.1 Data

Our sample includes a group of firms that meet the legal requirements concerning the management of different waste streams [1] within WEEE scope and a control [2] sample (from the same industry) that do not comply with those requirements imposed by law. The information about firms' compliance came from two lists from the actual management entities in Portugal for WEEE disclosed by Electrão and European Recycling Platform Portugal [3].

Then we matched that information with the SABI [4] database provided by Bureau Van Dijk to collect accounting data for the 2011–2019 period.

We exclude observations without available information on total assets and total sales. We also require that firms have a minimum of two employees each year. To reduce the effect of outliers, we winsorize all continuous variables at the 1% in each tail of the distribution.

Our final sample comprises 2,690 firm-year observations related to 354 firms from different industries within the WEEE scope. The treatment (control) group accounts 1715 (975) firm-year observations that correspond to 200 (154) firms. Panel A of Table 1 describes the treatment sample per the starting year that firms comply with the law and Panel B describes the treatment and control groups by industry.

As can be seen in Table 1, most firms started to comply with the law in 2006 and belong to the industry of wholesale trade, especially the electronic and telecommunications equipment trade, which also holds for firms in the control group.

Panel A – Sample description per the starting year that firms are in compliance with the law		
Year	# Obs.	# Firms
2006	638	71
2007	81	9
2008	98	11
2009	320	36
2010	36	4
2011	43	5
2012	16	2
2013	102	13
2014	57	7
2015	128	17
2016	43	6
2019	40	5
2020	113	14
Total	1,715	200

Panel B – Sample description by industry					
Group		Treatment		Control	
NACE	Definition	# Obs.	# Firms	# Obs.	# Firms
261*	Manufacture of electronic components and boards	27	3	17	3
271*	Manufacture of electrical equipment	36	4	29	4
2733	Manufacture of wiring devices	9	1	15	2
2740	Manufacture of electric lighting equipment	143	17	102	15
275*	Manufacture of domestic appliances	63	7	41	7
2790	Manufacture of other electrical equipment	68	8	40	7
3313	Repair of electronic and optical equipment	25	3	19	3
4321	Electrical installation	131	15	33	6
4647	Wholesale of furniture, carpets and lighting equipment	108	12	83	13
4652	Wholesale of electronic and telecommunications equipment	400	46	247	38
4690	Non-specialized wholesale trade	454	53	309	50
4778	Other retail sale of new goods in specialized stores	251	31	40	6
	Total	1,715	200	975	154

Note(s): Panel A describes the number of observations ("# Obs.") and the number of firms ("# Firms") by the year that firms in treatment group started to comply with the law. Panel B describes the sample (treatment and control) by industry identified by 4-digit classification NACE (statistical classification of economic activities in the European Community), except codes 261, 271 and 275, which include all 4-digit codes within that classification

Table 1.
Sample description

3.2 The model

To examine the effects of regulation compliance on innovation, we modelled the following equation using a difference-in-differences (DID) framework.

$$\begin{aligned} Innov_{i,t} = {} & \alpha_i + \beta_1 Treat_{i,t} + \beta_2 Post\ compliance_{i,t} + \beta_3 Post\ compliance_{i,t} \times Treat_{i,t} \\ & + \gamma_1 Size_{i,t-1} + \gamma_2 Roa_{i,t-1} + \gamma_3 Leverage_{i,t-1} + \gamma_4 Sales\ growth_{i,t-1} \\ & + \gamma_5 Investment_{i,t-1} + \gamma_6 GDP_{i,t-1} + \mu_i + \eta_j + \varepsilon_{i,t} \end{aligned} \quad (1)$$

where $Innov_{i,t}$ is a measure of corporate innovation ability for firm i in year t captured by two proxies: (1) the number of copyrights and granted patents measured as a logarithm, and (2) the logarithm [5] of intangibles. Consistent with prior research, we adopted the number of copyrights and patents (Goh *et al.*, 2019; Faurel *et al.*, 2017) and the value of intangibles [6] (Barron *et al.*, 2002; Potepa and Welch, 2017) as the result of innovation activities. $Treat_{i,t}$ is an indicator variable that equals one if firm i is included in our treatment group, and zero otherwise. Our treatment group includes firms that comply with the requirements imposed by law regarding the waste management; $Post\ compliance_{i,t}$ is an indicator variable that equals one starting in the compliance year and zero otherwise. Our variable of interest is $Post\ compliance_{i,t} \times Treat_{i,t}$, which captures the changes in innovation post-compliance with the waste management regulation.

To control the firms' attributes, we include *Size*, profitability measured as *Roa*, *Leverage*, *Sales growth*, and *Investment* in fixed assets. *Size* is the natural logarithm of total assets that is included to control the impact of firm size in corporate investment decisions, namely in intangible assets; it is expected that larger firms invest more (in absolute figures) in innovation (e.g. R&D expenses that drive to intangibles recognition) than smaller firms, however, on the other hand, some prior studies defend that smaller firms generate more patents per currency unit invested in R&D than larger firms (Kim *et al.*, 2009). *Roa* is an indicator of corporate performance measured as earnings before interest and taxes scaled by total assets; here the rationale is that more innovative firms will display more volatile cash flows, which drives to higher profitability but also to an increase in the default risk (Ericson, 1995). *Leverage* is the long-term debt over total assets and is included as a measure of corporate financial risk; activities that lead to innovation (e.g., R&D) are more prone to be financed by internal funds than by debt (Hall and Lerner, 2010). *Sales growth* is widely used in prior studies (Loureiro and Silva, 2020) to capture growth opportunities assuming that firms that have grown well so far are better prepared to continue to grow in the future. *Investment* is a proxy for corporate investment, measured as the annual percentage change in fixed assets that competes with investment in intangibles for financing. Previous evidence shows that investing in fixed assets is less risky than investing in intangible assets due to economic uncertainty relating to intangibles, which can lead managers to channel investment to fixed assets instead of assets without physical substance (Ferrer *et al.*, 2020).

We summarize in Table 2 the predicted relation between the main variables included in equation (1) and the dependent variables.

To account for unobservable time-variant characteristics that might impact the behavior of our dependent variables, we include *GDP Growth* measured as the annual percentage growth rate of real GDP gathered from Eurostat. In some regressions, we will use year dummies as an alternative measure of GDP. All variables are defined in Appendix.

Variables	Predicted sign	Assumption
Post-compliance × *Treat*	+	It is expected that regulation has a positive impact on innovation activities
Size	+/− (inconclusive)	Larger firms invest more (in absolute terms) in R&D activities, however, prior evidence suggests that smaller firms generate more innovative output per currency unit invested in R&D than larger firms
Roa	+/− (inconclusive)	More innovative firms are more prone to be more profitable, but they are also riskier
Leverage	−	Innovation is usually financed with firms' cash flows rather than debt
Sales Growth	+	It is expected that innovation will be positively related with growth opportunities
Investment	−	Investment in fixed assets competes with intangibles for financing

Table 2. Main variables included in equation

The control group is formed of firms that do not comply with the legal requirements of waste management and results from a matching procedure with the treatment group by the same year and industry and with the closest *Size*.

Our DID model also includes firm (μ_i) and industry (η_j) dummies. In the regressions, standard errors are clustered by firm and by industry to control for unobservable time-invariant characteristics of firms. In the empirical analysis, the number of observations is further reduced due to limited data availability for selected variables.

Table 3 reports the descriptive statistics for all variables used in the study for the full sample, and also for the treatment and control groups. As we can observe in Panel A of Table 3, firms are small in size, where *Total Assets* is under €5 million, and the median number of employees is about 10 over the 2011–2019 period. It is also noteworthy that only about one-third of our full sample reports values for intangibles and have published patents, which reveals that most firms do not appear to have a propensity to be innovative.

Panel B shows that the differences in means and medians between treatment and control groups of firms are statistically significant in most cases, at least, at the 5% level; firms are larger (*Size*), display more published patents, show more growth opportunities (measured by *Sales Growth*), are less levered (*Leverage*) and have more employees (on average) than control firms.

Although as shown in Panel B of Table 3 treatment and control firms present significant differences across variables, firms in the control group were selected as being as similar as possible with treated firms concerning the industry, year and *Size* as already explained. This process helps to mitigate potential problems of self-selection bias that could harm the statistical inference presented in Section 4.

3.3 Correlation analysis

In order to complement descriptive statistics, Table 4 presents the Pearson's correlation coefficients and its significance levels across all variables for the full sample.

We observe that our proxies for innovation (logarithm of the number of patents and the logarithm of intangibles) are positively correlated, which means that firms capitalize part of the R&D expenses as patents. Regarding the correlation between dependent and control variables, we observe that dependent variables are positively correlated with *Size* and the number of employees, and negatively correlated with the investment in fixed assets (*Investment*). These coefficients are as predicted because is expected that larger firms invest more in innovation and invest (proportionally) less in fixed assets than smaller firms.

4. Empirical results and discussion

As already mentioned, our variable of interest is $Post\ compliance_{i,t} \times Treat_{i,t}$, which captures the changes in innovation after firms meet legal requirements for management waste (our treatment group), relative to the control group of firms that do not comply with those requirements. According to our prediction, we expect that compliance with waste management regulation has a positive impact on innovation, i.e. that treated firms increase their innovative ability after starting to comply with the law. Table 5 provides the results.

Created management entities in Portugal are obliged to perform the tasks transposed from the Commission Decision 2004/249/EC, promoting a green and circular economy approach. In this context, we postulate as our research hypothesis that firms that comply with WEEE regulation are more innovative.

The coefficients' estimates displayed in Table 5 show a positive and significant change in the number of patents and in the value of intangibles after firms comply with the waste

Table 3. Descriptive statistics

Panel A – Descriptive statistics

Group	Full sample *N*	Full sample Mean	Full sample Median	Full sample Std. Dev.	Treatment *N*	Treatment Mean	Treatment Median	Treatment Std. Dev.	Control *N*	Control Mean	Control Median	Control Std. Dev.
Innovation proxies												
Number of Patents	844	3.7000	0.0700	12.9095	623	4.7600	1.0000	16.1227	221	0.2666	0.0000	0.5412
Ln(Intangibles)	987	1.6651	1.2959	2.4580	670	1.8808	1.6688	2.5005	317	1.2090	0.5971	2.3038
Control variables												
Total Assets	2,690	4,559	1,358	12,728	1715	5,460	1,239	15,304	975	2,973	1,525	5,579
Roa	2,690	0.0545	0.0437	0.0982	1715	0.0552	0.0460	0.1020	975	0.0534	0.0407	0.0912
Leverage	1916	0.1627	0.1132	0.1670	1,276	0.1559	0.1071	0.1646	640	0.1762	0.1215	0.1709
Sales Growth	2,690	0.0519	0.0220	0.2797	1715	0.0673	0.0442	0.2792	975	0.0248	0.0090	0.2787
Investment	2,648	0.3323	−0.0245	1.9416	1,681	0.3583	−0.0262	2.0923	967	0.2871	−0.0200	1.6472
Nr. Employees	2,686	32.52	10.00	111.94	1711	36.92	10.00	129.62	975	24.80	10.00	70.35
GDP	2,690	1.09%	2.02%	2.14%	1715	0.80%	1.79%	2.27%	975	1.61%	2.02%	1.76%

Panel B – Univariate comparisons between treatment and control groups

	Differences in means (treatment – control)	*t*-test	*p*-value	Differences in medians (treatment – control)	*Z*-test	*p*-value
Innovation proxies						
Number of Patents	4.4934	3.75	0.000***	1.0000	4.31	0.000***
Ln(Intangibles)	0.6718	4.05	0.000***	1.0717	4.58	0.000***
Control variables						
Total Assets	2,488	4.90	0.000***	−286	3.11	0.002***
Roa	0.0018	0.45	0.644	0.0053	2.31	0.021**
Leverage	−0.0203	−2.50	0.012**	−0.0144	3.33	0.002***
Sales growth	0.0425	3.80	0.000***	0.0352	4.62	0.000***
Investment	0.0712	0.90	0.364	−0.0062	2.81	0.005***
Nr. Employees	12.12	2.70	0.007***	0.0000	0.79	0.433

Note(s): Panel A provides descriptive statistics for the full sample over 2011–2019 and for treatment and control groups. For each variable, we report the number of observations ("*N*"), the mean, the median, and the standard deviation ("Std. Dev."). All variables are defined in Appendix. Panel B reports the differences in means (medians) between treatment and control groups. Differences in means are tested using the *t*-statistic test and differences in medians are tested using the Wilcoxon rank sum test. *** and ** mean statistical significance at the 1 percent level and 5 percent level, respectively

Table 4.
Correlation matrix

	Nr. patents	*Ln(Intangibles)*	*Treat*	*Size*	*Roa*	*Leverage*	*Sales growth*	*Investment*	*# Employees*
Nr. patents	1								
Ln(Intangibles)	0.258***	1							
Treat	0.088***	0.150***	1						
Size	0.314***	0.495***	−0.014	1					
Roa	0.038*	−0.029	0	0.054***	10				
Leverage	0.035	−0.139***	−0.047*	−0.130***	−0.189***	1			
Sales Growth	−0.068***	0.041	0.041**	−0.065***	−0.022	0.029	1		
Investment	−0.031	−0.043	0.023	−0.107***	0.038*	0.02	0.147***	1	
# Employees	0.322***	0.321***	0.067***	0.482***	0.048**	−0.118***	−0.035*	−0.027	1

Note(s): This table reports the correlation matrix for all main variables of our full sample over 2011–2019. All variables are as described in Appendix. ***, ** and * mean statistical significance at the 1 percent level, 5 percent level and 10 percent level, respectively

Dependent variable	Ln(number of patents)			Ln(Intangibles)		
Model	(1)	(2)	(3)	(4)	(5)	(6)
Treat	−0.0352*	−0.0352*	−0.0352*	−1.1208*	−1.1798*	−1.1208*
	(−1.75)	(−1.76)	(−1.30)	(−1.74)	(−1.82)	(−1.90)
Post-compliance	−0.0314*	−0.0317*	−0.0314*	−2.2001***	−2.3959***	−2.2001***
	(−1.87)	(−1.88)	(−1.36)	(−3.29)	(−3.29)	(−5.66)
Post-compliance × *Treat*	0.0280*	0.0284*	0.0280*	1.7956*	2.0125*	1.7956***
	(1.67)	(1.68)	(1.26)	(1.81)	(1.94)	(3.09)
Size	−0.0024*	−0.0023*	−0.0024*	0.0860	0.0523	0.0860
	(−4.06)	(−3.99)	(−1.92)	(0.28)	(0.16)	(0.46)
Roa	−0.0006*	−0.0006*	−0.0006*	0.7899	0.9711	0.7899
	(−0.43)	(−0.51)	(−0.40)	(0.71)	(0.86)	(0.83)
Leverage	−0.0078*	−0.0081*	−0.0078*	0.2988	0.3279	0.2988
	(−4.43)	(−4.47)	(−1.97)	(0.38)	(0.41)	(0.19)
Sales Growth	0.0115*	0.0111*	0.0115*	2.1771***	2.1595***	2.1771***
	(0.61)	(0.59)	(0.51)	(3.66)	(3.62)	(6.05)
Investment	0.0175*	0.0174*	0.0175*	−0.1580***	−0.1571***	−0.1580***
	(1.33)	(1.31)	(1.11)	(−12.16)	(−9.30)	(−11.68)
GDP	0.0064*		0.0064*	7.0256		7.0256
	(2.46)		(1.75)	(1.46)		(1.22)
Constant	−0.0176	−0.0179*	−0.0176	1.4571	1.4842	1.4571
	(−0.42)	(−0.42)	(−0.39)	(0.61)	(0.61)	(1.29)
Observations	822	822	822	677	677	677
R-squared	0.852	0.854	0.852	0.852	0.854	0.852
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	No	Yes	No
Cluster	Firm	Firm	Industry	Firm	Firm	Industry

Note(s): This table provides regression estimates of Equation (1). Dependent variables are proxied by (1) the logarithm of the number of copyrights and granted patents, and (2) the logarithm of intangibles. $Treat_{i,t}$ is an indicator variable that equals one if firm i is included in our treatment group, and zero otherwise. $Post\ compliance_{i,t}$ is an indicator variable that equals one starting in the compliance year and zero otherwise. All variables are defined in Appendix. Regressions include firm, industry and year fixed effects in different schemes. Standard errors are clustered by firm in models 1–2 and 4–5, and by industry-level in models 3 and 6. Robust t-statistics in parentheses ***, ** and * mean statistical significance at the 1 percent level, 5 percent level and 10 percent level, respectively

Table 5. The impact of compliance on innovation

management regulation. Leading companies will be led to invest in product, process and marketing innovation, in order to ensure an important competitive advantage in terms of consumer purchase decisions, especially in the context of regional innovation and entrepreneurship ecosystems (Farinha *et al.*, 2020). In addition, entrepreneurship and innovation associated with the green economy can help the regions to move towards a "sustainable eco-economy," reinforcing its position as part of the Triple Bottom Line, highlighting the increase of well-being social level (Dean and Mcmullen, 2007).

These results are consistent across estimations after controlling for other factors that can affect the outcome of dependent variables. Using model (4) as an example, after compliance, firms increased their intangibles value (measured as a logarithm) in 1.8. This represents about 6,000€ in intangibles' total value. Such evidence gives confidence to support our research hypothesis 1.

Regarding the coefficients of the control variables, and as predicted, *Size* is negatively related to the number of patents suggesting that smaller firms register more patents per currency unit invested in R&D; however, that does not impact the total value of intangibles. *Roa* and *Leverage* are also negatively related to the number of patents meaning that more innovative firms are riskier and R&D activities are mainly financed with internal funds. As expected, more innovative firms have more growth opportunities (as measured by *Sales Growth*), and fixed *Investment* competes with intangibles for financing (as they are negatively related).

The economic magnitude of coefficients across estimations are very similar, but they might vary due to different fixed effects schemes. Using industry, year and firm fixed effects might control for several invariant and unobservable characteristics not captured by the baseline estimations (i.e. using GDP, industry, and firm fixed effects), which might affect the outcome magnitude.

Several challenges and opportunities arise in this matter, involving interactions between academia, industry, government, and civil society, specifically at the level as in this collaborative context, companies provide products and services in order to achieve sustainable competitiveness in the marketplace (Peris-Ortiz *et al.*, 2016).

Circular economy intents to transform waste into future resources and leverage production and consumption activities (Witjes and Lozano, 2016) giving rise to the creation of an economy where the outputs of one value chain become inputs for another next chain, generating economic value, reducing the consumption of virgin materials, in parallel with the use of waste and environmental decontamination (Klitkou *et al.*, 2019; Savini, 2019).

5. Conclusions and implications

5.1 Key findings

The objective of this paper is to investigate entrepreneurship from the perspective of circular economy and waste collection within WEEE scope in the Portuguese context. For such, a group of Portuguese firms that met, or not, the legal requirements concerning the management of different waste streams within WEEE was used. The information about compliance came from two lists from the actual management entities in Portugal for WEEE disclosed by Electrão and European Recycling Platform Portugal, many authors argue that regulation compliance is the most important innovation driver (Porter and Van Der Linde, 1995).

WEEE directive resulted from 2004/249/EC Commission Decision regarding the Waste Electrical & Electronic Equipment, this directive was transposed to all member states in the following year. In Portugal such occurred in 2005 as compulsory to all sectors within the WEEE scope. Initially, the recovery target was 4Kg per inhabitant per year and later redefined to 65% of the weight of new products placed in the market. The root of this directive is a green economy based on sustainability and a transition from a linear economy model to a circular economy model. Since the Industrial Revolution, companies and consumers have largely adhered to a linear model of value creation that begins with extraction and concludes with end-of-life disposal. Resources were acquired, processed using energy and labor, and sold as goods with the expectation that customers will discard those goods and buy more (Bouton *et al.*, 2016; Ruiz-Real *et al.*, 2018).

On the other hand, the circular economy model includes resource efficiency in order to extend the product's useful life, that is, delay its end of use, this model is less dependent on the extraction of virgin resources, as the recycling of waste from discarded products becomes a source of new material resources to incorporate in the manufacturing of new products, thus, avoiding the pollution and exhaustion of new resources. Circular Economy aims to deliver a better alternative to the actual economic model, the so-called "take, make and dispose" (Ness, 2008). On the transition of a linear to circular model, we can also observe the basis of the green economy, as manufacturing operations, delivery processes and waste management become significant aspects to society, academia, governments, and industry (Hsieh *et al.*, 2017).

The entrepreneurial ecosystem encompasses the vision of the ecosystem entrepreneurs, investigating on how entrepreneurs should align their vision, goals, and structures with those of the ecosystem leader (Nambisan and Baron, 2013). In this context, entrepreneurship can help regions move towards a sustainable and ecological economy, furthermore, increasing social welfare (Dean and Mcmullen, 2007).

Our results point out that a large number of firms are small and medium-sized (SME) and started to comply with the law in 2006 and belong to the industry of wholesale trade, especially the electronic and telecommunications equipment trade, on the other most firms do not show propensity for innovation. Five percent of the firms are larger on size, display more published patents, show more growth opportunities, disclose higher profitability and on average have more employees.

Moreover, the results prove that complying with the legislation is a factor of innovation which reflects on the companies' engagement with sustainability (Freeman, 2015) and increases the awareness on environmental management (Claver-Cortés *et al.*, 2007), furthermore it defines a relationship with stakeholders (Scarpellini *et al.*, 2019). Business may use the gathered results in their ecosystem in two ways: primarily with managers to help on their decisions, secondly to inform stakeholders (Scarpellini *et al.*, 2019) on new products, services, waste management, environmentally friendly practices and social activities related to environment.

Furthermore, this will improve organizations goodwill towards the ecosystems and improve engagement with stakeholders (Schaltegger and Burritt, 2005). Nevertheless, some the organizations will only be compliant with environmental regulation, as it mandatory, may affect company's business results, image or to avoid penalties (Berrone *et al.*, 2013).

According to our prediction, we expect that compliance with waste management regulation has a positive impact on innovation, i.e. firms will increase their innovative ability after starting to comply with the law. Larger firms are more innovative and invest more in innovation and invest (proportionally) less in fixed assets than smaller firms.

Moreover, we could observe a positive and significant change in the number of patents and in the value of intangibles after firms comply with the waste management regulation. Firms increased their intangibles value (measured as a logarithm) in 1.8. This represents about 6,000€ in intangibles total value.

Some limitations were found throughout this research that are important to point out, which will be helpful for future studies.

The market value of innovation is difficult to assess in a consistent and systematic way, which limited researchers' ability to make reliable inferences about the more accurate metrics to measure it (Trajtenberg, 1990; Alcácer *et al.*, 2009; Potepa and Welch, 2017). Hence, the main limitation in our study is related to the measures designed to capture innovation activities, proxied by the number of patents and the value of intangibles. Even using the number of patents instead of their currency value is not considered sufficiently informative about firms' innovative output (Trajtenberg, 1990). However, our research focuses on a single country, which helps to overcome such inaccuracy.

Furthermore, it is noteworthy to emphasis that proxies used in this study were conditioned by data availability. Indeed, the sample although with substance could not help in some areas as more than 90% of the companies in Portugal are SMEs with scarcity on financial and operational information. This research should be replicated in a future stage with information from other member states with larger firms.

Furthermore, we advise that future research should be linked to geographical country areas, in the case of our research it was not possible to trace in a direct link (i.e. using NUTT's).

5.2 Implications of the study

The results of the research are significant as they involve a great number of stakeholders: Society, Industry, Governments, Academia. As we could see throughout the research, there is no effective link amongst these key players. The circular economy in Portugal is at an embryonic phase, which may justify the present lack of collaboration between the actors in the ecosystem. We expect that our research may shine towards a future effective collaboration amongst those parties. The Ellen MacArthur Foundation is a collaborative center for the Academia, legislators and companies and provides incentives for the different actors to cooperate with each other (Geissdoerfer *et al.*, 2017).

The implementation of circular business models enables the development of regional business networks that help to create local jobs in the regions where they operate. It is elemental that companies embrace a circular economy, and sustainable policies in Europe till 2030 to specialize in the collection, processing, manufacturing and sale of products/services based on a circular business model. Consumers are increasingly aware of the benefits of sustainable products, which is likely to increase the sustainable growth in the entrepreneurial ecosystems (Nascimento *et al.*, 2019).

Governments and local policy makers have to make all the necessary efforts to publicize EU initiatives on sustainability and circular economy amongst companies. Currently, there are already companies that pay a close attention to the environment, even incorporating the concept in their core business, to achieve a sustainable growth. However, most managers are not well informed about EU policies, as well as the financial cost of the investment on the essentials to implement them in their business (Agyemang *et al.*, 2019).

Regarding knowledge, the Academy is not developing new courses, or adapt those already in place to cover the new reality that tackles sustainability, green economy, symbiosis industry and circular economy. The Academy could potentially raise extra income from the available European funds, which may be useful to apply in research projects.

Regardless the importance of the concept of circular economy, the conceptual relationship between the circular economy and sustainability is currently unclear for the Industry, Academia, Governments (Geissdoerfer *et al.*, 2017), our research is a contribution for this clarification.

The actual literature although abundant, does not link all the concepts discussed within this paper (i.e. Entrepreneurial ecosystems with circular economy). This offers a good opportunity to investigate a new research area of how different stakeholders could work in a more systematic way to achieve both environmental and business goals at the same time, thereby ensuring overall sustainability (Hsieh *et al.*, 2017).

Our research added contributions to the literature on the innovation proxies. As Innovation is hard to measure (Potepa and Welch, 2017) and is mostly based on trademarks and patents, these traditional measures of performance can be threatening innovations to firms that are frequently overlooked and undervalued by market participants (Christensen, 2003). Our conclusions point out that compliance may be a proxy to explain innovation in this particular sector. According to Potepa and Welch (2017) numerous fields in the academy have conveyed an aspiration for valid proxies for innovation, as not all the existing proxies consistently measure a firm's innovation, being so, compliance can be an incentive for top management to encourage innovation in their firms (Baranchuk *et al.*, 2014).

Notes

1. The legal requirements include the management of waste from electric and electronic equipment (WEEE), batteries and accumulators waste, and packaging waste.
2. The treatment and control groups were matched by the same year and industry and with the closest *Size*.
3. See more at http://www.electrao.pt; https://erp-recycling.org/pt-pt/produtores-erp/.
4. SABI is an *Iberian Balance Sheet Analysis System* provided by Bureau Van Dijk (a Moody's Analytics Company).

5. The dependent variables were measured as logarithms to reduce heteroscedasticity issues regarding the scale of remaining variables in the model.
6. The International Accounting Standard (IAS) 38 outlines the requirements for accounting intangible assets, which are defined as nonmonetary assets without physical substance but identifiable and able to produce future benefits for a corporation. Examples of intangibles are computer software, licenses, trademarks, patents, films and copyrights. See more at: https://www.iasplus.com/en/standards/ias/ias38; https://www.ifrs.org/issued-standards/list-of-standards/ias-38-intangible-assets/.

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Appendix

Variable	Definition	Source
Firm-level		
Number of patents	Number of granted copyrights and patents over the 2011–2019 period	SABI
Ln(Intangibles)	The total value of intangible assets measured as a logarithm	SABI
Size	Logarithm of total assets	SABI
Roa	Earnings before interest and taxes (EBIT) divided by total assets	SABI
Leverage	Long-term debt divided by total assets	SABI
Sales Growth	Sales growth is measured as the percentage change in sales over year t–1 to t	SABI
Investment	Annual percentage change in fixed assets	SABI
Total Assets	Total Assets in thousands of Euros	SABI
Total sales	Total net sales in thousands of Euros	SABI
Employees	Number of employees	SABI
Country-level		
GDP	Annual percentage growth rate of real GDP at market prices based on constant local currency	Eurostat
Industry-level		
NACE code	4-digit NACE (statistical classification of economic activities in the European Community)	SABI

Table A1. Definitions and Sources of the variables

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