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REGULAR ARTICLE

On the adoption of circular economy practices by small and medium-size enterprises (SMEs): does "financing-as-usual" still matter?

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Abstract

This paper investigates the extent to which the adoption of Circular Economy (CE) practices by Small and Medium-sized Enterprises (SMEs) correlates with the choices they make in their financing. Referring to the debate about CE business models (CEBM) and intersecting it with emerging research on the CE barriers/enablers revealed by SMEs, we focus on the argument that "financing-as-usual", by relying on standard financial sources according to the "pecking-order-theory", could not work in supporting the CE transition of SMEs. Using data on more than 2000 European SMEs from the 2016 Eurobarometer, we instead find that financing as usual still matters for the sake of CE. Self-financing (extended to some forms of capital sources) appears a significant enabler of the adoption of generic CE practices, as well as debt financing, and the latter matter less than the former, consistent with the "pecking-order-theory". Public funds do also matter, having a larger impact than self-financing, but a lower one than debt financing. On the other hand, not only does the availability of alternative forms of financing not support CE(BM), but it even crowds-out the resort to CE, possibly in favor of more linear-risk activities. With some few interesting exceptions, the previous results are confirmed when the adoption of specific kinds CE(BM) practices is considered, as well as the SMEs' capacity of extending their portfolio.

Keywords Circular economy · Eco-innovations · SMEs · Financial sources

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1 Introduction

Moving towards the Circular Economy (CE) represents nowadays an imperative objective. Production and consumption systems based on the linear model of 'Take, Make, and Dispose' are neither environmentally sustainable, nor economically convenient anymore (EMAF 2015a). A shift is required towards a new "circular" paradigm based on the 'Reduce, Reuse, and Recycle' of resources, which allows one to "close the loop" in the functioning of economic systems (EC 2015), providing environmental and economic benefits at different levels of analysis (EEA 2016; WEF 2014).

At the firm level, the CE occurs through a number of practices – e.g. prioritizing regenerative resources, converting and eliminating waste, designing durable and reassemblable products, combining products and services in 'pay-per-use' or, more in general, 'product-service-systems' (PSS) – that allow for important opportunities of cost savings and revenue streams (Stahel 2013). However, moving business towards the CE is far from simple. A growing stream of literature shows that CE requires firms to change substantially their business model (Linder and Williander 2015), searching for alternative ways of creating, delivering and capturing value (Accenture 2014). In turn, the adoption of CE business models (CEBM) requires important 'second-order' changes in the core-capabilities of the firm and its relationships with the partners along the value-chain (Lewandowski 2016).

Among the pre-conditions of CEBM, an important one has been recognized only recently, and mainly by non-academic research and financing institutes, about the way firms acquire resources to support their transition towards the CE. In particular, some recent reports (see, for example, FinanCE Working Group 2016 and ING Departments of Economics 2015) have argued that "financing as usual" might not work with the CE. Standard forms of capital (e.g. debt vs. equity) would have a limited degree of consistence with the new kind of 'circular-risk' that the CE entails. Furthermore, CEBM appear so heterogeneous in their risk profile, that "no-one-fits-all" financial instrument would exist with respect to the CE, and their adoption would instead require new competencies of financing tailoring.

While certainly relevant, the previous arguments have been developed by inspecting a number of CEBM cases of both start-ups – e.g. Bundles (selling of washing cycles) – and consolidated companies – such as Philips (the "pay-per-lux" PSS) (FinanCE 2016; ING Departmens of Economics 2015) – which require wider discussion and evidence to be validated. This is the aim of this paper, which looks at how firms finance the implementation of CE practices that eventually affect their adoption.

Although the issue at stake is a general one, in the present paper we focus on the CE practices of Small and Medium-sized Entreprises (SMEs) in Europe. This specific focus has a twofold motivation. First of all, as SMEs represent the dominant share of its industrial structure and generate most of its employment, the European transition towards the CE is arguably dependent on that of its SMEs. Second, SMEs have been found to be more seriously hampered by the inadequacy of standard financial sources in supporting the CE transition, and in conjunction with other kinds of size-specific barriers (Murillo-Luna et al. 2011; Trianni and Cango 2012; Rizos et al. 2015, 2016).

Given the paucity of rigorous and systematic empirical studies on the topic, we fill this research gap by empirically analyzing data on more than 2000 European SMEs, exploiting the survey Flash Eurobarometer-441 on "European SMEs and the Circular

Economy" of 2015. In particular, we investigate the role that standard and non-standard financial sources have in the SMEs' adoption of generic CE practices, of characteristic practices of specific CEBM, and in the composition of their portfolio of CE activities.

The rest of the paper is structured as it follows. Section 2 positions our research question in the debate about the financing of CEBM and integrates it with that on SMEs in front of the CE. Section 3 illustrates our empirical application. Section 4 discusses its main results and Section 5 concludes.

2 Background literature

In broad terms, research on the CE has been splitting into two main domains, pertaining to the enabling conditions that policy-makers can activate (EMAF 2015a) and to those on which economic actors (firms in particular) can intervene (Ghisellini et al. 2016). Within the latter stream of research, an important field of study is developing about the opportunity of inserting "circularity" into the firm business model[1] and about the way of implementing such an insertion through CEBM (Boken et al. 2014, 2016).

Research on CEBM has paid special attention to the drivers and barriers that affect their adoption, identifying them both within the firm and in its "external environment".[2] Among these factors, an important role has been recognized to the risks that the adoption of CEBM could entail (Linder and Williander 2015) and to its effects on their financing (FinanCE Working Group 2016). At the outset, it has been claimed that the transition towards the CE entails a brand-new category of risk, which the partners of the FinanceCE Co.project (2016) have termed 'circular risk'. Not only is there radical uncertainty about the expected demand for CE consistent products, given the customers' habits of owning (rather than 'servicing') and valuing them in single (rather than repeated) life-cycles, but uncertainty also concerns the firm's capacity of reframing linear supply-chains into closed-loop ones, given the lack of information of chain actors about the residual value of the assets in which they are expected to invest. According to standard financial principles, these two circular risk components will affect the financier's capacity to recuperate its capital and will make the subject claim a 'premium-risk' to support the adoption of a CEBM rather than of a linear business model.[3]

Given the risk at stake, financing the adoption of CEBM becomes a critical issue and assumes novel nuances with respect to the financing of eco-innovations (EI): innovations with a positive environmental impact (e.g. reducing the use of energy, water and materials, and attenuating the emission of polluting substances) (Horbach et al. 2012), of which CE practices could be considered a special case. As recent research has shown (Cecere et al. 2018; Scarpellini et al. 2014), the particular nature of these EI actually

[1] Among the several definitions provided in the management literature, the business model is here taken to illustrate generically "the rationale of how an organization creates, delivers and captures value" (see Osterwalder and Pigneur 2010).

[2] Among the former are the expected demand for future/circular products (Planing 2015), the firm's human resources (Laubscher and Marinelli 2014), its ICT and systems of data management (Scott 2015). The latter have been mostly identified in the institutional system and legislative setting of the firms' host country (EMAF 2015a; Linder and Williander 2015)

[3] To be sure, a 'linear risk' does also exist in financing standard (linear) business models, for example, because of their reliance on exhaustible/exhausting virgin resources and on the exposition to the price volatility of such resources (FinanCE Working Group 2016).

makes the search for funding for their introduction/adoption particularly problematic. EI are subject to a so called "double externality": not only do they suffer from standard knowledge externalities, such as standard innovations, but also from environmental externalities (Rennings 2000). This feature, along with the higher complexity and the novelty of their knowledge-base (Carrillo-Hermosilla et al. 2010), makes EI more problematic to manage and increases the chances to observe technological lock-ins and path-dependency at the advantage of dirtier (more established) technologies (Cecere et al. 2014; Oltra and Saint Jean 2009). This suggests that EI are riskier and accordingly harder to get collateralized and financed than standard innovations, making their financing a crucial issue to address from a policy point of view (Cecere et al. 2018). Indeed, public policies have been recognized as crucial to solving this manifold failure of EI and accordingly put at the core of the agenda to support the 'Grand Challenges' of meeting societal, environmental and economic goals through innovation (Foray et al. 2012). Governmental intervention, by means of public funding and, more broadly, of setting environmental regulation, is actually crucial for the uptake of (radical) EIs and for supporting their early-stage deployment and subsequent diffusion (Ghisetti 2017). Furthermore, in addition to its direct effect, public funding can also increase the firm's capacity of eco-innovating indirectly, that is, by complementing, supporting and augmenting the effectiveness of its external finance (Cecere et al. 2018).

Representing a particular case of EI, CE practices suffer from similar problems. Accordingly, also with respect to CE, public funds have emerged as crucial, not only to help firms addressing their double externality, but also to alleviate their difficulties in adopting radically new and, as we said above, quite risky CE business models: the substantial investment of resources that the EU has made into its packages of CE transition is clear proof of that (EC 2014, 2015). However, when it comes to CE, and to CEBM, an additional issue seems to emerge: not only do they require support to their financing, but they also need an innovative kind of financing, in at least two respects. On the one hand, it has been claimed that standard forms of financing, such as debt vs. capital as well as the firm's resort to internal financing, would not be generally suitable to deal with the premium risk that the support to CE would entail. Alternative instruments would instead be necessary to increase the CE alignment with the financial domain.[4]

On the other hand, it has also been argued that different forms of capital would fit different typologies of CEBM, in light of their heterogeneous risk profile, so that a "one-fits- all" CE financial instrument should not be targeted either. In this last respect, the taxonomies that professional and/or consulting institutions have recently built up (also) to illustrate the financial implications of CEBM can help us appreciate the point. For example, looking at their focus on the different steps of the product-life-cycle, the FinanCE Co.project (2016, p. 75) has aggregated the five CEBM previously identified by Accenture (2014)[5] into three typologies, with different risks profile and non-standard financing requirements. The first typology, identified as 'Circular *Innovation* Modes' (CIM), focuses on the development phase and is based on product innovations

[4] Among these instruments, some have been identified already in factoring and reverse factoring with respect to PSS, supply-chain finance and collaborative chain financing in waste-based CE practices and in CE based on eco-design (for details, see FinanCE Working Group 2016).

[5] These are: 1) circular supplies, 2) resource recovery (waste as a resource, and recycle), 3) product life extension (remanufacture, resell, and repair/upgrade), 4) share, and 5) product as a service.

(e.g. newly designed products easier to repair) and/or process innovations (e.g. new and/or re-engineered processes to increase recyclability and waste streams) through which the CE value-logic is implemented. The second CEBM is represented by 'Circular *Use* Modes' (CUM) and aims at extending the use of already realized products, either by retaining their ownership and selling their services to the customers (as in PSS), or by offering maintenance and add-ons services once sold. Finally, 'Circular *Output* Models' (COM) are developed in the after-use phase and aim at transforming used products into new ones or into useful resources, mainly by reducing if not eliminating their waste residual. As Table 1 illustrates in a schematic way, the three models actually differ among them in their risk profile and in the extent to which "standard" forms of financing can support their adoption.

As we said, the inner and heterogeneous nature of CE suggests two arguments about their financing, which have been so far empirically evaluated only on the basis of specific case-studies. On the one hand, CE practices would apparently make unsuitable the resort to standards financial sources, as they for example feature the common "pecking order" theory in finance studies (Myers and Majluf 1984). According to it, firms should prioritize the use of internal financing and move to equity only as a last resort, after having experienced the debt channel. Given the circular and evolving nature of the risk that CE entails, the use of these instruments could be ineffective in the adoption of CEBM, as they are instead consistent with the adoption of more standard, linear business models. On the other hand, the highly heterogeneous risk profile of

Table 1 CEBM according to FinanCE: risk profile and required form of financing

Typology of CEBM	Focal phase of intervention	Risk profile	Form of financing
Circular *Innovation* Modes (CIM)	Newly designed products (e.g. easier to repair) and/or new and/or re-engineered processes (e.g. increase recyclability and reduce waste streams)	High technological and operational risk	High-risk debt capital (large up-front investments make risk decreases only gradually)
Circular *Use* Modes (CUM)	Existing products to be circularly used (e.g. PSS, or/and maintenance and add-ons services once sold)	High and wide financial risk (e.g. PSS: i) capital required to finance assets remaining in the balance-sheet; ii) cash-flow pressure due to diluted subscription/rental rates; iii) working capital required by misaligned new asset purchase (beginning of the lease contract) and entrance accumulation (lease fees) to cover costs; iv) less creditworthy customers	Alternative forms of financing than standard ones (e.g. leasing, reverse factoring, …)
Circular *Output* Models (COM)	After-use products to recycle and/or to reduce/eliminate waste residual	Mid/high technological and operational risk.	Low-risk debt capital not suitable

Source: our elaboration of FinanCE Co.project (2016, p. 75)

CEBM would prevent the identification of financial sources that support the CE transition invariantly with respect to the kinds of practices that are adopted. In brief, different sources of financing should map differently into different CEBM. Related to this is the role of financing in supporting the adoption of what we might term a "fully-fledged" CEBM, encompassing a variety of CE practices within the spectrum of the 'Reduce, Reuse, and Recycle' paradigm. As such a CEBM entails the composition of practices with different risk profiles (see above), and so supporting its adoption should be extremely risky, thus making the resort to financing-as-usual even less (or differently) effective than the adoption of generic and/or singular practices.

The aforementioned arguments are particularly relevant with respect to SMEs, on which we will focus in our empirical application. Although extant surveys reveal that the explicit adoption of CEBM is rarely declared by them, SMEs are increasingly recognizing the benefits of undertaking CE practices in their business activities (Hillary and Burr 2011; Rizos et al. 2015).[6] Despite its recognized potential, the CE transition poses to SMEs a number of size-specific problems, which could hamper its implementation.[7] Among these factors, the financial aspects illustrated above figure out prominently. At the outset, financial issues have been found to matter for the adoption of EI in general. In particular, recent studies have found that financial constraints significantly hamper the SMEs' adoption/introduction of EI (Ghisetti et al. 2017), and that public funds and fiscal incentives that SMEs receive are important in spurring their EI (Cecere et al. 2018; Scarpellini et al. 2014).

When it comes to CE practices, the main evidence discussed beforehand with respect to EI remains valid. Problematic access to finance appears a barrier for the uptake of CE more for SMEs than for large companies, for different reasons. First of all, SMEs are in general more financially constrained than large companies (Beck and Demirguc-Ku 2006; Lee et al. 2015) and would accordingly be more exposed to the borrowing costs of implementing the monitoring and improvement activities that CEBM usually require (Dervojeda et al. 2014). Second, the upfront costs and the delayed payback periods of a PSS kind of CEBM (e.g. via leases) turn out to be more important for SMEs than for large firms, given their higher sensitivity to the extra-costs of the search for resource efficiency. Third, the problem of the low residual value of the CE assets undermines the SMEs opportunities for bank financing to a greater extent than large companies, given their relative disadvantage in terms of collateral availability (Hyz 2011). Last, but not least, external financing turns out to be more difficult for SMEs also in front of EU and government grants, given the diffuse paucity of staff and management practices in evaluating and exploiting the available opportunities (Müller and Tunçer 2013).

Overall, previous arguments seem to suggest that, especially for SMEs, "financing-as-usual" might be problematic with respect to the adoption of CEBM. This appears to be confirmed by a recent survey (Rizos et al. 2016) of a (non-representative) sample of

[6] A survey recently conducted within the EU co-funded project FUSION has revealed that the majority of the 300 interviewed firms had never heard of CE, but had already taken substantial efforts in a number of CE aspects such as re-use and recovery of waste, recycling and repairing (FUSION 2014).

[7] As recent literature reviews of the topic have revealed, these obstacles refer to different domains, spanning from the lack of "hard" (technological) and "soft" (organizational) capital to the resistance of 'traditional' stakeholders, passing through the administrative burden of CEBM, which often clashes with the "lack of government support/effective legislation" (Rizos et al. 2016, p. 4).

52 SME case studies comprehending CE solutions, among those registered in the GreenEcoNet EC web-platform (2016). As many as 50% of the sample cases actually declared that a relevant barrier to their implementation has been the lack of initial financial capital, as well as the lack of forms of capital alternative to private equity and bank lending, that is, to standard forms of financing. The lack of such an alternative appears particularly relevant in the case (20% of the sample) of firms reporting difficulties in accessing funding from traditional banks. These are actually depicted as inflexible in respect to the new financial arrangements of the CE (e.g. the resort to lease) and, in general, incapable of realizing the economic opportunities of the CE.

All of the previous bits of evidence are case-based, if not even anecdotical. More systematic support about their holding is therefore needed before rejecting the opposite conclusion, that standard forms of financial sources and standard ways of resorting to it – such as the pecking-order-theory - still matters for the sake of CEBM. This is the purpose of the empirical analysis outlined into the next section.

3 Empirical application

Our empirical analysis refers to a sample of 2318 SMEs in the 28 Member States of the European Union from the 2016 Flash Eurobarometer-441 on "European SMEs and the Circular Economy" (https://data.europa.eu/euodp/data/dataset/S2110_441_ENG). This is a survey containing information about the CE activities undertaken by the sample firms in the three years preceding 2015 and on a set of structural (e.g. size) and conjunctural (e.g. turnover trend) characteristics of them. In spite of its cross-sectional nature - hampering the identification of causal relationships - and its Flash nature (i.e. just based on Computer-Assisted Telephone Interviewing (CATI)) - posing possible respondent-biases - the survey has a rich coverage of questions (see http://ec.europa.eu/environment/green-growth/docs/fl_441_sum_en.pdf), from which the focal variables of our analysis can be built.

3.1 Variables

We build up three focal dependent variables, which make different uses of the CE practices foreseen by the Flash Eurobarometer questionnaire.[8] The first one is a variable, *CIRC*, which detects the eventual "entrance" of the focal firm in the CE domain, from whatever of its "doors". This is a dummy, taking value 1 if the firm has adopted at least one of the five following practices: 1. re-plan the way water is used to minimize usage and maximize re-usage; 2. use of renewable energy; 3. re-plan energy usage to minimize consumption; 4. minimize waste by recycling or re-using waste or selling it to another company; 5. redesign products and services to minimize the use of materials or use recycled materials.

The second dependent variable tries to proxy the heterogeneity of CEBM we have illustrated above. Unfortunately, the five alternatives provided to the respondents about

[8] The full harmonized questionnaire is available, without registration, at the following link. Upon registration, data can be downloaded from the same link (https://dbk.gesis.org/dbksearch/sdesc2.asp?no=6779&db=e&doi=10.4232/1.12668)

CE practices (see above) prevent us from mapping them accurately into the three kinds of CEBM to which we have referred in Section 2 (see Table 1). On the other hand, the same practices can still be grouped into three types of CEBM that, while sharing different distinguishing features from CIM, CUM, and COM, can still be expected to have heterogeneous financial implications. A first class of CEBM can be identified as Circular *Input* Mode and encompasses practices that target a circular employment of energy and water inputs by the firm, pursued through either innovative or non-strictly innovative behaviors. This can be proxied by a dummy, *CInputM*, taking value 1 if the firm has undertaken at least one (or more) of the practices 1, 2, and 3 above. A second typology can instead be more directly referred to the Circular Innovation Mode we have addressed in Section 2 and, for the sake of distinction, denoted by the variable *CInnoM*: a dummy that takes value 1 if the firm adopts practice 5, encompassing an innovative redesign of products and services for the sake of their more sustainable use. Finally, in close relationship with the previously defined Circular Output Mode, we can consider a *Circular Waste Mode*, proxied by a dummy, *CWasteM*, equal to 1 if the firm has undertaken practice 4 and focused on the reduction, if not even elimination of waste. As Table 2 reveals, the taxonomy of CEBM that we are capable of capturing apparently misses one of the most problematic of them, that is, the Circular Use Mode (CUM) of Table 1. On the other hand, it could be claimed that such a mode is somehow subsumed by *CInnoM*, as the innovation practices to which it refers are intended to intervene on the "use" of virgin or recycled materials. Accordingly, this latter model can be expected to have the highest risk profile among the three, while the new one we encompass – that is, *CInputM* – is arguably that with the lowest.

Our third dependent variable proxies the size of the firm's portfolio of CE practices. In a way, this could provide us with insights about the relative position of the focal SMEs with respect to a fully-fledged CEBM, in which all of the CE practices that we have considered (*CInputM*, *CInnoM*, and *CWasteM*) are adopted: *CNumbM,* counts the number of undertaken CE practices, ranging from a minimum of 1 to a maximum of 5.

The explanatory variables on which we focus refer to the way in which firms declared to have financed the undertaking of CE activities and to their reporting about the availability of financial instruments at the company level, which could support the adoption of CE. Crossing the alternatives provided to the respondents with the standard typologies of financing crystallized by financial studies and practices, we build up the

Table 2 CEBM according to the Eurobarometer: kind of CE practices

Typology of CEBM	CE practice
Circular Input Mode (CInputM)	re-plan the way water is used to minimize usage and maximize re-usage; or/and use of renewable energy; or/and re-plan energy usage to minimize consumption
Circular Innovation Mode (CInnoM)	redesign products and services to minimise the use of materials or use recycled materials
Circular Waste Mode (CWasteM)	minimize waste by recycling or re-using waste or selling it to another company

Source: our elaboration of the 2016 Flash Eurobarometer-441

following four dummy variables. *PUB_FIN* refers to the role that public funds have been shown to have in supporting the adoption of general EI (Ghisetti et al. 2017; Cecere et al. 2018) and of CE practices in particular. It takes value 1 if the firm has used EU related funds and/or national government grants for the sake of CE or it has declared to have used "any financial incentives through government programs supporting activities related to the CE", and 0 otherwise. The other four financial dummies make an eclectic use of the "pecking-order" theory (Myers and Majluf 1984) when its application to SMEs and data availability are considered. A first amendment to this approach is imposed by the nature of firms we observe with respect to the first step of the theory, namely, self-financing. SMEs in general do not have limited liability and a large share of them are established under a legal form with unlimited liability (Eckardt 2014). Accordingly, the resort to equity is for them quite infrequent and often substituted by the provision of "internal" capital (for example, in the form of money transfers within family firms) and, especially recently, by less risky forms of capital financing such as crowdfunding. On this basis, we build up a dummy, *SELF_CAPITAL_FIN*, which takes value 1 when the resort to self-financing appears either alone or together with capital in the way we have said. A third dummy, *DEBT_FIN*, refers to the second step of the pecking order theory and takes value 1 if the firms has declared to have adopted CE practices by benefiting from bank loans, either of a general or of a specific green nature, or it has declared the availability of green banks or other private institutions stimulating CE and green investments. The fourth and last dummy tries to capture the role that newly devised forms of financial assistance to firms could have for the adoption of CEBM. Unfortunately, firms have not been asked about the actual use of these tools for the sake of CE, but rather about their availability at the company level. Accordingly, we build up the dummy *ALTERN_FIN*, which takes value 1 if one or more of alternative sources of financing – such as venture capital, business angels, and peer-to-peer lending – is available in the firm. In other words, in the absence of more specific information requests about their actual use, we assume that, having declared them available within a focal survey about their CE, the interviewed firms have actually used these alternative forms of financing for CE to a certain extent. While this might lead to overestimating the role of *ALTERN_FIN*, we deem that not using it at all would entail an inconvenient loss of information for the sake of our research question.

In addition to these focal financial variables,[9] we consider other explanatory factors of the adoption of CEBM plus a set of controls. First of all, following the regulatory push/pull approach to EI (e.g. Horbach et al. 2012), of which CE activities can be considered as a special case, we try to account for its four components: i) the "market-pull effect"; ii) the "technology-push effect"; iii) firm-specific characteristics; and iv) environmental regulations. We proxy the market role in the adoption of CE through a variable measuring the past economic performance of the firm, namely a dummy signalling whether its turnover has grown in the relevant period of time, namely in

[9] As for these focal financial variables, it should be noted that, in their analysis of EI by SMEs, Cecere et al. (2018) also address the possible complementarity between (i.e. co-occurrence of) public funds and private source of financing, finding evidence of it with respect to external financing. Unfortunately, the very limited number of cases in which our sample firms resort simultaneously to a public and a private form of financing (descriptive statistics available from authors upon request) prevents us from carrying out a similar kind of complementary analysis with respect to CE and forces us to postpone it to our future investigation.

the three years preceding 2015 (*TURNGROWTH_D*). We have been forced to construct the variable as such, as no continuous alternative about turnover was available. Although the knowledge sources to introduce CE innovations possibly cover other intangible investments, such as design (with respect to EI, see Ghisetti and Montresor 2018), available data just allow us to consider the R&D investments of the firm, in percentage of its turnover (*RDinv*). As for the specific characteristics of the focal firms, we first consider their size, in terms of employment (in log, *SIZE*), and their age, through a dummy for them being *YOUNG*, established after January 2015. The survey unfortunately does not report the real age of the firm, but only if established after January 2015, between 2010 and 2015 or before 2010. We then try to retain firm-specific barriers to the adoption of CE practices by using a variable (*BARS*), which is the first principal component obtained from the consideration of the different obstacles presented to the respondents by the Eurobarometer questionnaire (e.g. lack of human resources and expertise, complexity of administrative or legal procedures, cost of meeting regulations or standards, and financial difficulties).[10] The industry in which firms operate is captured through sectoral dummies. Finally, in dealing with the role of environmental regulations, we found that, given that our unit of analysis is the firm, the use of country-level indicators, such as the famous OECD Environmental Policy Stringency, would entail the loss of much of the heterogeneity due to sub-national measures (for a discussion Mazzanti et al. 2016). As good proxies for them at a more disaggregated level are hard to find (Albrizio et al. 2017), we proceed in two ways. In a first specification, we augment the model that accounts for CE with the full set of country-sector dummy interactions, which would capture country-sector variability of environmental regulations. As an alternative specification, we include in the model the full set of regional (NUTS2 level) dummies, as most of the environmental regulations occur at this level of analysis or above. This approach would allow us to capture most of the variation due to different environmental regulations in our sample.

Table 3 summarizes the variables that we use and provides their descriptive statistics. Table 4 reports the Spearman correlation matrix for these variables, from which problems of multi-collinearity seem to be absent.

3.2 Econometric strategy

Consistent with our research questions, the econometric strategy that we follow is articulated in three steps. First of all, we estimate a set of probit models to investigate the firm's probability of adopting any kind of CE practice, using *CIRC* as dependent variable. We thus estimate the following knowledge production function, where our knowledge-related dependent variable, ($y_1 = CIRC$) pertains to the adoption of eco-innovative CE practices:

$$P(y_1 = 1 | D, X, Z) = \Phi(D'\beta_1 + X'\beta_2 + Z'\gamma) \quad (1)$$

In Eq.(1) Φ is a standard cumulative normal function, D is the vector of our four financial variables, X and Z the (other) CE determinants and firm-specific controls we have been able to capture. We then augment this baseline specification with the full set

[10] Details on the construction of the variable *BARS* are provided in Appendix A.1

Table 3 Main variables statistics

Variable	N	Mean	Sd	Min	Max
ALTER_FIN	2318	0.16	0.37	0	1
BARS	2318	0.24	0.33	0	1.26
CInputM	2318	0.29	0.46	0	1
CIRC	2318	0.68	0.47	0	1
CNumbM	2318	1.47	1.38	0	5
CWasteM	2318	0.32	0.47	0	1
CInnoM	2318	0.16	0.37	0	1
SIZE	2318	1.67	1.44	0	5.517
DEBT_FIN	2318	0.16	0.37	0	1
PUB_FIN	2318	0.05	0.22	0	1
RDinv	2318	2.98	11.98	0	100
SELF_CAP_FIN	2318	0.54	0.50	0	1
TURNGROWTH_D	2318	4.93	2.29	1	8
YOUNG	2318	0.20	0.40	0	1

of country-sector interaction terms to account for any country sector specific fixed effect and, alternatively, by the full set of regional NUTS2 fixed effect. Standard errors are clustered by country.

The second step of our analysis looks at the adoption of the three kinds of CEBM we have been able to identify with the available data, namely *CInputM*, *CInnoM*, and *CWasteM*. At the outset, we run a probit estimation for each and every of these three dependent variables, by using the same set of covariates and controls of Eq. (1) (Table 7). However, the adoption of one CEBM cannot be treated as independent from that of another, and the intersection between CInputM, CInnoM and CWasteM is not null. Accordingly, we account for the correlation of their relative disturbances by estimating a multivariate probit model for the three CEBM with a simulated Maximum Likelihood approach. In doing that, the same set of covariates of Eq. (1) is still exploited.[11] Let us note that the appropriateness of the multivariate probit is also confirmed by: i) the significant correlations that the three variables display among them, all above 0.3 (Table 4); ii) the statistical significance of the correlation coefficients "rho" (Table 9).

The third and last model that we estimate looks at the extent at which financial variables affect the number of CE practices that firms are capable to adopt with respect to a fully-fledge CEBM. Being *CNumbM* a count variable, spanning from 0 to 5, and still by using the same set of covariates as Eq. (1), we estimate a Poisson regression model similar to the following:

$$\Pr(y1 = y|\ \mu) = \frac{e^{-\mu}\ \mu^{y}}{y!}\ with\ (y = 0, 1, 2, 3, 4, 5) \tag{2}$$

[11] The Stata command "mvprobit" was used for that (Cappellari and Jenkins 2003).

Table 4 Spearman correlation matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	CNumbM	1.00													
2	CIRC	0.84	1.00												
3	SIZE	0.16	0.13	1.00											
4	BARS	0.13	0.08	0.05	1.00										
5	YOUNG	−0.05	−0.04	−0.20	0.04	1.00									
6	TURNGROWTH_D	0.01	0.00	−0.03	0.00	−0.03	1.00								
7	PUB_FIN	0.18	0.14	0.07	0.12	−0.03	−0.01	1.00							
8	SELF_CAP_FIN	0.56	0.63	0.10	0.10	0.00	0.00	−0.03	1.00						
9	DEBT_FIN	0.15	0.14	0.04	0.12	0.01	0.00	0.10	−0.02	1.00					
10	ALTER_FIN	0.07	0.06	−0.01	0.11	0.07	−0.02	0.03	0.15	0.28	1.00				
11	RDinv	0.18	0.12	0.07	0.11	0.05	−0.03	0.08	0.12	0.08	0.12	1.00			
12	CInputM	0.59	0.45	0.05	0.06	−0.02	0.00	0.13	0.29	0.13	0.08	0.12	1.00		
13	CInnoM	0.45	0.30	0.04	0.05	−0.01	0.00	0.09	0.25	0.05	0.08	0.16	0.32	1.00	
14	CWasteM	0.50	0.47	0.07	0.06	−0.02	0.00	0.08	0.31	0.10	0.07	0.08	0.36	0.38	1.00

and $\mu = \exp.(D'\beta_1 + X'\beta_2 + Z'\gamma)$

4 Results

Our first set of results refers to the firm's capacity/probability to adopt CE practices that could be indicative/prodromal of a generic CEBM. Table 5 shows that all the financial variables we have considered correlate significantly with *CIRC*, suggesting that the CE does actually have an important financial side, which would deserve more attention in the future. In particular, it seems that the "circular" risk, which has been claimed to hamper the effectiveness of standard financial instruments in driving the adoption of CEBM, does not inhibit them yet in the case of SMEs.

Table 5 Probit results on CIRC

	CIRC	CIRC	CIRC
SIZE	0.0629***	0.0860***	0.0695***
	(0.0179)	(0.0155)	(0.0195)
BARS	−0.0755	−0.0791	−0.0404
	(0.1511)	(0.1583)	(0.1693)
YOUNG	−0.1512*	−0.1325	−0.1917**
	(0.0875)	(0.0865)	(0.0924)
TURNGROWTH_D	−0.0076	−0.0019	−0.0031
	(0.0155)	(0.0157)	(0.0195)
RDinv	0.0034	0.0022	0.0039
	(0.0035)	(0.0033)	(0.0038)
PUB_FIN	1.9853***	2.1302***	2.2216***
	(0.2073)	(0.2097)	(0.2062)
SELF_CAP_FIN	2.2386***	2.2757***	2.3836***
	(0.1385)	(0.1497)	(0.1434)
DEBT_FIN	0.8047***	0.8344***	0.7782***
	(0.1668)	(0.1860)	(0.1848)
ALTER_FIN	−0.3931***	−0.4934***	−0.3825**
	(0.1346)	(0.1481)	(0.1564)
Constant	−0.6851***	−0.7786***	−1.8919***
	(0.2417)	(0.1487)	(0.2882)
N	2318	2251	2144
pseudo R^2	0.4671	0.4645	0.4944
Country dummy	Y		
Sector dummy	Y	Y	
Region NUTS2 dummy		Y	
Country*Sector dummy			Y

Country-Clustered Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

As expected, the correlation is positive for all the focal variables but *ALTER_FIN*, which turns out significantly negative. While this could appear counterintuitive, a possible interpretation might be that, in the presence of alternative equity funds within the company – e.g., venture capital and/or business angels – SMEs might divert their efforts from CE possibly to embark into other non-CE activities, which could instead be marked by a "linear" kind of risk. In other words, the supposedly riskiest of the considered financial sources does not appear suitable to deal with a "circular" kind of risk, as would be expected, and are rather employed for other linear risk activities, which even crowds out the resort to CE.

The adoption of CE practices appears positively correlated with SMEs of a larger size and of an older age. This suggests that the adoption of CEBM could be favored by the presence of scale effects of technical and organizational nature, as well as by business experience in the relevant sector. On the other hand, when we do not focus on a specific kind of CEBM, as we will instead do in the following, making experience of generic CE practices does not seem to require technological knowledge (R&D is not significant) and is neither hampered by the "declared" barriers, nor favored by a positive market performance. In the model at stake, as well as in the following ones, *TURNGROWTH_D* does not appear significant. While somehow unexpected, this possibly suggests that the crucial role that the non-academic literature has recognized to market demand and consumer preferences/habits in driving CE (EMAF 2015a, b) could pass through a more articulated kind of proxy than a simple increase in the adopting firm's turnover.

The marginal effects of the probit estimates on *CIRC* (Table 6) appear consistent, although in terms of intensity rather than of a sequence rule, with the "reduced" version of the "pecking order" theory that we have been able to capture. Relying on self-financing and other related forms of capital is more correlated to the adoption of CE than debt financing. On the one hand, this confirms previous evidence about the difficulties that SMEs have been found to encounter in obtaining funds from banks and financial intermediaries for the sake of CE (Rizos et al. 2016). On the other hand, these difficulties are not so prohibitive as to cancel out a still relevant role of "standard" debt financing. Consistent with previous evidence (e.g. Cecere et al. 2018) is the importance that public financing has for the adoption of CE and/or CEBM. Indeed, although smaller than *SELF_CAPITAL_FIN*, the marginal effect of *PUB_FIN* is larger than that of *DEBT_FIN*. This suggests that relatively less "to-be-collaterized" forms of grants are searched and used by SMEs to enter in the CE domain.

When we move from the adoption of generic to specific kinds of CE practices and try to get closer to the adoption of particular CEBM, previous results are confirmed and do not seem to support the idea that a tailored kind of financing is necessary for them. Both probit (Table 7) and multivariate probit results (Table 9) show that the financing-as-usual variables we considered keep their significance across all the CEBM typologies, with only one but notable exception. CEBM focused on innovative (and possibly use-) oriented CE practices, *CInnoM*, appears the only typology that does not significantly correlate with debt financing. This could be due to the higher extent at which this typology, especially in its PSS variant, entails a technological (and possibly) circular kind of risk with respect to *CInputM* and *CWasteM*, which banks and/or private investors might find prohibitive. An additional element of differentiation with respect to the *CIRC* estimates concerns the role of *ALTER_FIN*. The retained alternative financial

Table 6 Marginal effects of explanatory variables on CIRC

	(1)	(2)	(3)
SIZE	0.0118***	0.0164***	0.0126***
	(0.0033)	(0.0029)	(0.0035)
BARS	−0.0142	−0.0151	−0.0073
	(0.0285)	(0.0303)	(0.0307)
YOUNG	−0.0284*	−0.0253	−0.0346**
	(0.0169)	(0.0170)	(0.0169)
TURNGROWTH_d	−0.0014	−0.0004	−0.0006
	(0.0029)	(0.0030)	(0.0035)
RDinv	0.0006	0.0004	0.0007
	(0.0006)	(0.0006)	(0.0007)
PUB_FIN	0.3727***	0.4064***	0.4014***
	(0.0456)	(0.0462)	(0.0442)
SELF_CAP_FIN	0.4202***	0.4342***	0.4307***
	(0.0054)	(0.0058)	(0.0067)
DEBT_FIN	0.1510***	0.1592***	0.1406***
	(0.0270)	(0.0299)	(0.0296)
ALTER_FIN	−0.0738***	−0.0941***	−0.0691**
	(0.0249)	(0.0285)	(0.0278)
N	2318	2251	2144

Average marginal effects (dy/dx) of all covariates on the discrete change of CE from 0 to 1 are reported. Note: dy/dx for dichotomous variables is the discrete change from the base level 0

Country-Clustered Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

sources do not exert on the adoption of specific CEBM the crowding out effect we have detected with respect to generic CE practices (their significance with respect to CWasteM is only marginally significant). In other words, when the SMEs targeting of a defined pattern of transition towards the CE is considered, this seems to stop a possibly alternative (i.e. linear-risk oriented) exploitation of available alternative financial sources, which could even dampen CE practices.

Quite interestingly, the multivariate probit results (Table 9) also show that, out of the three kinds of CEBM we have been able to proxy, those that correlate with R&D are *CWasteM* and especially *CInnoM*. Consistently with our positions (Table 2), practice 5 of the Eurobarometer (i.e. redesign products and services to minimize the use of materials or use recycled materials) is actually the most R&D dependent and thus innovative, with important implications in terms of technological and operational risk in their financing (Table 1): the lack of significance of *FIN-DEBT* with respect to *CInnoM* (see above) could also reflect this fact.

Some additional considerations about the three forms of CEBM that we have considered can be drawn from the marginal effects of the corresponding probit estimates (Table 8). After having discounted the non-significance correlation between *DEBT_FIN* and *CInnoM*, the order of importance between the different forms of financing we found in the previous specifications gets confirmed with respect to

Table 7 Probit estimates of CInputM, CWasteM and CInnoM

	CInputM	CInputM	CInputM	CWasteM	CWasteM	CWasteM	CInnoM	CInnoM	CInnoM
SIZE	0.0014	0.0101	0.0112	0.0409*	0.0604***	0.0472*	0.0255	0.0321	0.0260
	(0.0196)	(0.0219)	(0.0206)	(0.0235)	(0.0234)	(0.0270)	(0.0302)	(0.0329)	(0.0326)
BARS	0.0372	0.0544	0.0666	0.0397	0.0107	0.0731	0.0689	0.0633	0.0531
	(0.1065)	(0.1141)	(0.1260)	(0.0968)	(0.0922)	(0.1022)	(0.1283)	(0.1310)	(0.1378)
YOUNG	−0.0906	−0.0301	−0.1059	−0.0303	0.0222	−0.0646	−0.0500	−0.0098	−0.0814
	(0.0706)	(0.0832)	(0.0895)	(0.0679)	(0.0716)	(0.0827)	(0.0665)	(0.0713)	(0.0671)
TURNGROWTH_D	−0.0081	0.0019	−0.0084	−0.0018	0.0056	0.0047	0.0007	0.0137	0.0114
	(0.0115)	(0.0147)	(0.0135)	(0.0118)	(0.0138)	(0.0144)	(0.0194)	(0.0206)	(0.0238)
RDinv	0.0041	0.0031	0.0046	0.0051	0.0017	0.0043	0.0079***	0.0061*	0.0081**
	(0.0034)	(0.0033)	(0.0039)	(0.0038)	(0.0040)	(0.0042)	(0.0030)	(0.0032)	(0.0035)
PUB_FIN	0.6210***	0.7229***	0.6728***	0.3642***	0.4784***	0.3370**	0.4860***	0.6340***	0.4987***
	(0.1498)	(0.1504)	(0.1815)	(0.1325)	(0.1337)	(0.1454)	(0.1474)	(0.1387)	(0.1678)
SELF_CAP_FIN	0.8410***	0.9053***	0.8871***	0.8698***	0.9557***	0.9439***	0.8209***	0.9009***	0.9276***
	(0.0742)	(0.0778)	(0.0875)	(0.0832)	(0.0853)	(0.0938)	(0.0704)	(0.0713)	(0.0779)
DEBT_FIN	0.4113***	0.4940***	0.4179***	0.3177***	0.3670***	0.3455**	0.1227	0.1309	0.1489
	(0.1167)	(0.1230)	(0.1447)	(0.1045)	(0.1134)	(0.1395)	(0.1363)	(0.1416)	(0.1721)
ALTER_FIN	−0.0616	−0.0429	−0.0426	−0.1694**	−0.0868	−0.2177***	0.0785	0.1376	0.1118
	(0.0855)	(0.1026)	(0.0917)	(0.0729)	(0.1033)	(0.0810)	(0.0899)	(0.1031)	(0.1118)
Constant	−2.1396***	−1.2946***	−1.8625***	−2.5499***	−1.3544***	−1.9501***	−2.4429***	−1.8492***	−1.7806***
	(0.1610)	(0.1833)	(0.1622)	(0.2060)	(0.2022)	(0.2311)	(0.2205)	(0.1795)	(0.2203)
N	2318	2221	2079	2318	2138	2065	2309	2005	1905
pseudo R^2	0.1851	0.1720	0.2008	0.2436	0.1960	0.2610	0.1687	0.1467	0.1956
Country dummy	Y			Y			Y		

Table 7 (continued)

	CInputM	CInputM	CInputM	CWasteM	CWasteM	CWasteM	CInnoM	CInnoM	CInnoM
Sector dummy	Y	Y		Y	Y		Y	Y	
Region NUTS2 dummy		Y			Y			Y	
Country*Sector dummy			Y			Y			Y

Country-Clustered Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8 Marginal effects of explanatory variables on CInputM, CWasteM and CInnoM

	(1) CInput	(2) CInput	(3) CInput	(4) CWasteM	(5) CWasteM	(6) CWasteM	(7) CInnoM	(8) CInnoM	(9) CInnoM
SIZE	0.0004	0.0029	0.0031	0.0109*	0.0174***	0.0126*	0.0052	0.0072	0.0057
	(0.0054)	(0.0062)	(0.0058)	(0.0062)	(0.0067)	(0.0072)	(0.0061)	(0.0075)	(0.0071)
BARS	0.0103	0.0154	0.0187	0.0106	0.0031	0.0196	0.0140	0.0143	0.0116
	(0.0294)	(0.0321)	(0.0353)	(0.0258)	(0.0266)	(0.0273)	(0.0261)	(0.0295)	(0.0301)
YOUNG	−0.0250	−0.0085	−0.0297	−0.0081	0.0064	−0.0173	−0.0102	−0.0022	−0.0177
	(0.0195)	(0.0235)	(0.0251)	(0.0181)	(0.0206)	(0.0221)	(0.0135)	(0.0161)	(0.0146)
TURNGROWTH_D	−0.0022	0.0005	−0.0024	−0.0005	0.0016	0.0013	0.0001	0.0031	0.0025
	(0.0032)	(0.0041)	(0.0038)	(0.0032)	(0.0040)	(0.0039)	(0.0040)	(0.0046)	(0.0052)
PUB_FIN	0.1715***	0.2042***	0.1887***	0.0971***	0.1378***	0.0902**	0.0989***	0.1431***	0.1088***
	(0.0407)	(0.0426)	(0.0500)	(0.0352)	(0.0387)	(0.0387)	(0.0295)	(0.0305)	(0.0361)
SELF_CAP_FIN	0.2322***	0.2557***	0.2488***	0.2319***	0.2753***	0.2527***	0.1671***	0.2033***	0.2023***
	(0.0180)	(0.0203)	(0.0216)	(0.0190)	(0.0232)	(0.0212)	(0.0135)	(0.0138)	(0.0157)
DEBT_FIN	0.1136***	0.1395***	0.1172***	0.0847***	0.1057***	0.0925**	0.0250	0.0295	0.0325
	(0.0321)	(0.0338)	(0.0404)	(0.0273)	(0.0319)	(0.0367)	(0.0278)	(0.0323)	(0.0376)
ALTER_FIN	−0.0170	−0.0121	−0.0119	−0.0452**	−0.0250	−0.0583***	0.0160	0.0310	0.0244
	(0.0236)	(0.0291)	(0.0258)	(0.0194)	(0.0299)	(0.0216)	(0.0182)	(0.0228)	(0.0243)
RDinv	0.0011	0.0009	0.0013	0.0014	0.0005	0.0012	0.0016***	0.0014*	0.0018**
	(0.0009)	(0.0009)	(0.0011)	(0.0010)	(0.0011)	(0.0011)	(0.0006)	(0.0007)	(0.0008)
N	2318	2221	2079	2318	2138	2065	2309	2005	1905

Average marginal effects (dy/dx) of all covariates on the discrete change of CE from 0 to 1 are reported

Note: dy/dx for dichotomous variables is the discrete change from the base level 0

Country-Clustered Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

CInputM: self-financing matters more than public financing, which in turn appears more important than debt financing. The same order applies to *CWasteM* too, but with an interesting difference: the gap in magnitude between the marginal effect of *PUB_FIN* and *DEBT_FIN* is smaller. Those *CWasteM* that are based on waste - in terms of reduction, reuse or re-cycle - have a lower risk profile than the other CEBM, and thus makes them less problematic and more effective to be financed through SMEs' borrowing from external financers (Table 9).

The last set of results we report consider the SMEs' propensity to move towards a fully-fledged CEBM, *CNumbM*, that we proxied with the number of CE practices that firms declared to have adopted. Poisson estimates (Table 10) show that the SMEs capacity of being widely circular returns to be significantly correlated with their size

Table 9 Multivariate probit results for CInputM, CWasteM and CInnoM

	CInputM	CWasteM	CInnoM
SIZE	0.0013	0.0448**	0.0229
	(0.0225)	(0.0227)	(0.0252)
BARS	0.0246	0.0169	0.0484
	(0.0950)	(0.0964)	(0.1089)
YOUNG	−0.0875	−0.0349	−0.0510
	(0.0804)	(0.0822)	(0.0913)
TURNGROWTH_D	−0.0084	−0.0012	0.0022
	(0.0135)	(0.0138)	(0.0152)
RDinv	0.0040*	0.0052**	0.0074***
	(0.0024)	(0.0024)	(0.0025)
PUB_FIN	0.6274***	0.3643***	0.4940***
	(0.1314)	(0.1311)	(0.1373)
SELF_CAP_FIN	0.8544***	0.8773***	0.8693***
	(0.0669)	(0.0675)	(0.0809)
DEBT_FIN	0.4205***	0.3168***	0.1468
	(0.0836)	(0.0857)	(0.0946)
ALTER_FIN	−0.0557	−0.1573*	0.0784
	(0.0887)	(0.0909)	(0.0970)
Constant	−0.9117**	−0.0141	−1.5315***
	(0.4575)	(0.4582)	(0.5801)
Rho1		0.2985***	
		(0.0397)	
Rho2		0.3636***	
		(0.0435)	
Rho3		0.5010***	
		(0.0462)	
N		2318	

Country-Sector dummies included, Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10 Poisson estimates results for CNumbM

	CNumbM	CNumbM	CNumbM
SIZE	0.0542***	0.0458***	0.0568***
	(0.0091)	(0.0102)	(0.0100)
BARS	0.1296**	0.1145*	0.1241*
	(0.0592)	(0.0623)	(0.0685)
YOUNG	−0.0612	−0.0808*	−0.0386
	(0.0373)	(0.0434)	(0.0451)
TURNGROWTH_D	0.0058	0.0058	0.0110*
	(0.0072)	(0.0074)	(0.0067)
RDinv	0.0049***	0.0054***	0.0036*
	(0.0019)	(0.0017)	(0.0019)
PUB_FIN	0.4951***	0.5265***	0.5566***
	(0.0766)	(0.0834)	(0.0735)
SELF_CAP_FIN	1.0154***	1.0146***	1.0573***
	(0.0866)	(0.0900)	(0.0917)
DEBT_FIN	0.3448***	0.3402***	0.3572***
	(0.0836)	(0.0914)	(0.0880)
ALTER_FIN	−0.1566***	−0.1391***	−0.1811***
	(0.0467)	(0.0519)	(0.0455)
Constant	−0.6523***	−1.4871***	−0.6039***
	(0.1292)	(0.1307)	(0.1329)
N	2318	2318	2318
Country dummy	Y		
Sector dummy	Y	Y	
Region NUTS2 dummy		Y	
Country*Sector dummy			Y

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

and, though with negligible significance, with their being older. Quite interestingly, *CNumbM* does also correlate with R&D. Furthermore, when the firm's capacity of building up a portfolio of CE practices is considered, the variable BARS emerges significant for the first time, but with a positive sign. This apparently contradictory result could be interpreted by referring to recent research on innovation barriers (see D'Este et al. 2012). According to this literature, the presence of barriers could be positively associated with the firms' innovation status, as they could appear to them – that is, be "revealed" - because of and during the innovation process itself, and not only "deter" its occurrence (as a negative association would reveal). As Pellegrino and Savona (2017) have recently argued, in order to establish the actual nature, "revealed" rather than "deterring", of the barrier, we would need to exclude from the sample firms that are not interested in innovating. On the other hand, given that this is not the focal issue of the paper, we deem it inopportune to build up such a sample of potential

innovators by excluding remaining firms, as we would risk getting biased estimates (due to the ad hoc created sample selection) of our main regressors. Still, the fact that BARS turns out significantly positive only in the Poisson estimation of *CNumbM*, in which focal firms possibly add further CE practices once having innovated in the CE domain, appears coherent with our interpretation of BARS to CE being of a revealed nature.

As for our focal explanatory variables, the picture of the financial side of the CE that has emerged throughout the paper gets once more confirmed, with self-, public and debt financing all appearing relevant for the SMEs propensity to approach a fully-fledged CEBM. Confirmed also is the result about the possible crowding-out effect that the availability of alternative forms of financing has been found to have on the generic propensity to adopt any CE practice. Indeed, as we said, such a crowding-out effect appears to vanish only when SMEs appear to target specific kinds of CE practices, in particular those to which we have referred as *CInputM* and *CInnoM*. Available high-risk financial sources are apparently not diverted away from CE, in such a way to discourage it for the sake of alternative linear risk activities, only when a specific pattern of CEBM among the three we capture is in place, namely, *CInputM*, *CInnoM* and *CWasteM*. These results are confirmed when performing a sensitivity analysis that estimates the model by Negative Binomial regression (see Appendix A.2).

5 Conclusions

Financing CE practices and business models is emerging as a crucial aspect for their successful adoption. Case-based evidence, which has been the dominant source of empirical info so far, has recently shown that the financial source firms use to support their transition towards the CE is an important conditioning factor. This evidence has stimulated discussion about the financial side of the CE, although mainly out of the academic domain. In particular, it has been argued that the CE would entail a new kind of "circular-risk", which would make standard financing instruments unsuitable to the adoption of CEBM. Furthermore, it has been argued that different kinds of CEBM are heterogeneous in terms of risk and are thus differently affected by different financial sources, so that a general pattern of CE financial importance should not be searched for and expected. While developed with respect to firms of virtually any size, these arguments have appeared to apply also and above all with respect to SMEs. Indeed, these have been actually argued/shown as suffering from higher financial barriers than large companies in entering the CE realm, and to declare explicitly the inadequacy of standard financial sources.

In trying to provide more systematic conceptualization and empirical evidence about these arguments, in this paper we have carried out an empirical test of the relevance of standard vs. non-standard financing instruments in two CE domains. First of all, we have looked at their role in the adoption of generic CE practices, without considering their inner nature, that is, in the capacity of firms to approach the CE realm. Second, we have inspected whether and eventually how financing instruments correlate with specific kinds of CEBM, and with the firm's capacity of building up a portfolio of CE practices, which could constitute a fully-fledge CEBM.

Exploiting data provided by a recent Eurobarometer survey, we have carried out such a test with respect to a large sample of more than 2000 European SMEs in 2015. The

conclusions we can draw on the obtained results and the entailed policy implications are the following. First of all, in spite of what has emerged from the debate on CE financing, CE(BM) appear still enabled by financing-as-usual patterns of fund raising, confirming what has instead emerged from more systematic evidence about the adoption of general eco-innovations by SMEs (Ghisetti et al. 2017; Cecere et al. 2018). In particular, it seems that the "circular" kind of risk that has been claimed to hamper the effectiveness of standard financial instruments in driving the adoption of CEBM – i.e. self-capital-financing and debt-financing – has not yet inhibited them in the case of SMEs. Although future research should look for more evidence about that, and with respect to large firms too, policy makers should pay more attention to the existing financial enablers of the CE and address the market failures that might hamper their operation.

Second, results have shown that, in non-financial terms, entering the CE domain, from whatever "door" - through any kind of CE practice - is less demanding than moving towards a fully-fledged CEBM - that is, according to the Eurobarometer, a Circular Input, Innovation and Waste Business Model (CNumbM). On the other hand, these two CE transition patterns share similar financing implications, especially with respect to the possible crowding-out effect, which the availability of alternative financial sources seem to exert on CE. Financial implications are instead different when SMEs appear to target a specific kind of CEBM among the ones we have considered. The crowding-out effect of alternative financing does vanish with respect to each and every one of these business models. Furthermore, Circular Innovation Modes apparently entail such a high technological and operational risk as to make the resort to debt financing exceptionally ineffective. In this case too, further research should investigate whether this argument applies to other kinds of CEBM. Still, a policy implication already emerges from that, regarding the opportunity of tailoring the public support to the CE, but by looking at the extent to which firms approach and/or have already approached the CE. In particular, policy makers should consider that, in general, promoting the development of alternative sources of financing might not help and may even contrast the CE transition.

Third, CE financing by SMEs has appeared generally consistent – though in terms of intensity rather than of sequence order – with the pecking-order arguments that we have been able to test with respect to them, but with an important specification. While self-financing matters more than debt financing, public financing appears in the middle as a fundamental source, which makes the direct support of policy makers crucial for the promotion of CE. Once more, this has emerged with respect to the generic and the multiple adoption of CE practices. On the other hand, targeting specific CEBM has shown some deviations from it, in the case of Circular Waste Modes centered on waste management. With respect to them, debt-financing exceptionally appears to be nearly as important as public financing. On this basis, while the policy support to the functioning of the financial sources/markets of CE could be informed by the premises of the pecking-order theory, this should foresee sufficient margins of flexibility in the support of specific CEBM practices.

Compliance to ethical standards

The authors declare that they comply to the ethical standards of the Journal.

Conflict of interest The authors declare that they have no conflict of interest.

Appendix

Principal Component Analysis (PCA) for constructing the variable BARS: barriers to the adoption of CE

The variable BARS captures the presence of innovation barriers perceived by the firm. The questionnaire asks firms to report "Have you encountered any of the following issues when undertaking activities related to the circular economy? Please indicate all that apply" (Question number 3):

1. Lack of human resources
2. Lack of expertise to implement these activities
3. Complex administrative or legal procedures
4. Cost of meeting regulations or standards
5. Difficulties in accessing finance
6. Other

BAR is constructed by capturing the first principal component of the above six possible barriers, obtained by performing a principal component analysis on the six variables. This first principal component captures most of the variance of those barriers: 62% (Table A1). All the six variables share the same direction of the first principal component, being positively correlated to it (Table A2).

The Likelihood Ratio Tests for Principal Components supports for the non-independence of the 6 variables.

Table 11 Factor analysis to construct BARS

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	3.70067	2.90661	0.6168	0.6168
Factor 2	0.79406	0.31152	0.1323	0.7491
Factor 3	0.48254	0.02406	0.0804	0.8295
Factor 4	0.45848	0.13816	0.0764	0.9060
Factor 5	0.32032	0.07639	0.0534	0.9593
Factor 6	0.24393	.	0.0407	1

Method: principal-component factors, Retained factors = 1, Rotation: orthogonal varimax (Kaiser off)

Likelihood Ratio Tests for Principal Components: chi2(15) = 6898.98 Prob > chi2 = 0.0000

Table 12 Rotated factor loadings (pattern matrix) and unique variances

Variable	Factor1	Uniqueness
Lack of human resources	0.78	0.39
Lack of expertise to implement these activities	0.86	0.26
Complex administrative or legal procedures	0.84	0.29
Cost of meeting regulations or standards	0.85	0.27
Difficulties in accessing finance	0.79	0.37
Other	0.53	0.71

Table 13 Negative Binomial estimation results – Sensitivity analysis

	(1) CNumbM	(2) CNumbM
SIZE	0.0467***	0.0389***
	(0.0124)	(0.0133)
BARS	0.1153**	0.0997*
	(0.0542)	(0.0578)
YOUNG	−0.0600	−0.0754
	(0.0468)	(0.0494)
TURNGROWTH_d	0.0078	0.0081
	(0.0076)	(0.0081)
PUB_FIN	0.4999***	0.5297***
	(0.0644)	(0.0693)
SELF_CAP_FIN	0.9974***	0.9956***
	(0.0427)	(0.0451)
DEBT_FIN	0.3344***	0.3271***
	(0.0469)	(0.0500)
ALTER_FIN	−0.1489***	−0.1239**
	(0.0511)	(0.0544)
RD	0.2341***	0.2419***
	(0.0414)	(0.0445)
Constant	−0.6586***	−1.5745***
	(0.1238)	(0.5097)
N	2318	2318
pseudo R2	0.150	0.174
Country dummy	Y	
Sector dummy	Y	Y
Region NUTS2 dummy		Y

LR test of alpha = 0: chibar2(01) = 1.4e-04, Prob > = chibar2 = 0.495

Table 14 List and definitions of the adopted acronyms

Acronym	Definition
CE	Circular Economy
CEBM	Circular Economy Business Model
CIM/CInnoM	Circular Innovation Modes
CUM	Circular Use Modes
COM	Circular Output Models
CInputM	Circular Input Models
CWasteM	Circular Waste Models
EI	Eco-innovations
PSS	Product-Service-Systems
SMEs	Small and Medium Enterprises

Results of the robustness check estimates of CNumbM: Negative Binomial Regression

As a robustness check of the results presented in Table 10 for CNumbM, in the following, we provide its estimation by a Negative Binomial regression. As Table 13 shows, the results we got in terms of significance and sign of the focal financial regressors are substantially confirmed and thus appear robust

On the other hand, it should be first noticed that our data do not suffer from an over-dispersed outcome variable, as the likelihood ratio test does not reject the null hypothesis that alpha equals zero. This test, meant to compare the negative binomial with the Poisson model, suggests that the latter is more appropriate across all the specifications. Second, the estimate of our original model through a Negative Binomial presented problems of convergence when using R&D (RDinv) as a continuous variable; this had to be transformed in a dummy - taking value 1 in the presence of any positive investment in R&D and 0 otherwise – in order to reach it (still, we could not achieve any convergence when exploiting the full set of country*sector interactions even by using such a dummy (spec (3)). Because of this transformation, the results of the Negative Binomial Regression are not fully comparable with the ones based on the Poisson

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