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Sustainable production: The economic returns of circular economy practices

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Abstract

Assessing the economic consequences of sustainable production choices aimed at reducing negative environmental externalities is crucial for policy making, in light of the increasing interest and awareness experienced in recent EU policy packages. This assessment is one of the goals of the current work, which tries to provide new empirical evidence on the economic returns of circular economy practices, drawing on previous literature on the underlying determinants of greener production choices, which are stated to differ from standard technological innovations as they are subject to a knowledge and an environmental externality. Using an original dataset on approximately 3000 Italian manufacturing firms, we provide evidence on the relations among innovations related to the circular economy concept and economic outcome in the short run. The evidence shows that in the short run, it is difficult to obtain economic gains from circular economy related innovations when taken in isolation, especially for Small and medium-sized enterprises (SMEs), who may also experience negative returns.

KEYWORDS
circular economy, economic return, firm competitiveness, sustainable production

1 | INTRODUCTION

The literature on the economic returns of sustainable production choices is already very rich. However, it still does not lead to any conclusive evidence pertaining to its economic consequences.

One of the first contributions arguing in favour of the potential positive effects of environmental innovation (EI) comes from the seminal paper by Porter and van der Linde (1995), which postulates that environmental regulation is not necessarily detrimental to firms' performance. When environmental policies are well designed, regulation-induced innovation may generate positive effects in the long run, leading to 'win–win' solutions that counterweigh the costs of compliance. Jaffe and Palmer (1997) articulate the hypothesis in its narrow, weak and strong characterizations, and it is only under the latter that efficiency gains achieved by an 'induced innovation' can completely offset the loss of competitiveness that has been caused by compliance (to policy) costs. A broad strand of empirical literature has focused on assessing the competitiveness effects of environmental regulation, or, in other terms, the strong version of the Porter hypothesis, which indirectly or directly passes through innovation, or more precisely, EI adoption, and this is where the current work is positioned. Likewise, the natural-resource-based view of the firm hypothesizes that firms' profitability and competitiveness can be positively affected by EI through the competitive advantages that are created once accounting for the natural environment surrounding the firm.

Overall, the existing literature agrees that the question 'does it pay to be green?' needs to be better qualified in terms of any sustainable production choice that is considered. Leaving environmental policy behind the scenes of the empirical analysis, and given the focus on a single country (Italy), the current work focuses on innovation activities directed towards circular economy practices to understand whether short-term economic gains (or losses) exist associated with those activities.

More precisely, we answer the question of which type of green practice has to be adopted to generate positive economic returns among EIs for a circular economy (CE-related EI). We contribute to a very recent and still developing literature, needing confirmation and empirical evidence, on the potential benefit of the circular economy for firms (Dey et al., 2020; Khan et al., 2021). We aim to fill the gap in the research area on the relation between CE-related EI and economic performance, and contextually, we shed further light on the more general relation between EI and firms' economic performance. To do that, we rely on a unique dataset for a sample of approximately 3000 Italian manufacturing firms.

The organization of the paper is as follows. The next section discusses the general conceptual modes through which EIs and CE influence firms' economic performance, developing the research questions. Section 3 illustrates the empirical strategy and discusses the results. The last section is left to the conclusions.

2 | ECONOMIC RETURNS AND ENVIRONMENTAL AND CIRCULAR ECONOMY INNOVATION

Recent literature agrees that mixed findings are found when studying the economic returns of greener production choices. Telle (2006) concludes that the real challenge would be to unveil when or for whom it can pay to go green, rather than posing the too general question of whether it pays or not to be green, as negative (Greenstone et al., 2012; Rexhäuser & Rammer, 2014; Sarkis & Cordeiro, 2001; Wagner et al., 2002), null (Amores-Salvadó et al., 2014; Elsayed & Paton, 2005; Peneder et al., 2017; Rubashkina et al., 2015) and positive (Cheng et al., 2014; Costantini & Mazzanti, 2012; Dowell et al., 2000; Endrikat et al., 2014; King & Lenox, 2001; Lanoie et al., 2011; Manello, 2017; Russo & Fouts, 1997; Salama, 2005) competitiveness or profitability returns have been empirically depicted in the literature. As reported in Barbieri et al. (2016), 'EI may influence in an asymmetric way short-term measures of profitability (e.g., stock market returns, profits) and long-term performance (e.g., productivity, international competitiveness, survival, and firm growth)' (Barbieri et al., 2016, p. 609).

The meta-analysis of the literature by Horváthová (2010) summarizes that 15% of the studies found a negative return of going green, 55% a positive return and 30% found no significant effect.

An economic explanation for the positive findings comes from the natural-resource-based view of the firm: The inclusion of environmental aspects is a proactive reaction to resource depletion that may threaten a firm's resources (Hart & Dowell, 2011). This reaction is, in turn, able to foster the development of strategic resources and dynamic capabilities (Aragón-Correa & Sharma, 2003; Hart & Milstein, 2003) that are later associated with positive economic returns (Hart, 1995) via a better market evaluation of the firm, access to new markets or cost reduction driven by increased resource efficiency (Ambec & Lanoie, 2008; Margolis & Walsh, 2003; Orlitzky et al., 2011; Porter & Kramer, 2002, 2006) and innovation (Martinez-Conesa et al., 2017) or the derived demand for green technologies induced by regulation that increases innovative firms' market value (Colombelli et al., 2020).

However, negative returns may also be explained. For instance, Soltmann et al. (2015) perform a sectoral analysis on 12 OECD country sectors (Austria, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, the United Kingdom and the United States) in the period 1980–2009 and approximate EI through patent applications and suggest the presence of a U-shaped relation between environmental patents and value added. For most industries, increases in EI negatively affect performance, while for others, they improve performance. This would suggest strong sectoral heterogeneities, which have also been confirmed by Riillo (2017) on Italian SMEs with a focus on labour productivity, leading the author to conclude that greener firms in energy-intensive sectors show no significant difference in performance than other firms. Mixed findings can also be explained by the lenses of economic growth. Leoncini et al. (2019) focus on a panel of Italian firms and find that their growth is more affected by green technologies than nongreen ones, with the exception of struggling and rapidly growing firms, and the firm's age plays a key role in shaping this relation. Marin and Lotti (2017) assess the effects of environmental patents on productivity on a panel of Italian manufacturing firms, showing that the productivity returns of EI are smaller than those related to nonenvironmental technologies. In fact, EI tends to crowd out nonenvironmental innovations, which may be even more profitable (Marin, 2014).

The reason why it is important to make such a distinction in the types of innovation considered and to better qualify the question is that firms' profitability depends on whether firms choose to introduce end-of-pipe technologies or to redesign their production processes and services. The first are not associated with any changes in firms' resources or capabilities and are thus not expected to produce any positive economic return in the short run (Cleff & Rennings, 1999; Russo & Fouts, 1997). For instance, Ghisetti and Rennings (2014) show, on a sample of German firms, how different typologies of EI may lead to heterogeneous profitability effects: EI aimed at improving resource, and energy efficiency has a positive influence on financial performance, but, on the other hand, those aimed at reducing externalities, such as harmful materials and air, water, noise and soil pollution, are associated with a worsening of financial performance. Miroshnychenko et al. (2017) provide a novel and global empirical overview of the financial returns of green practices by analysing a panel of publicly traded companies in 58 countries over 13 years, showing that what they define as internal green practices (pollution prevention and green supply-chain management) are the major drivers of financial performance, whereas product development is secondary and the adoption of environmental management schemes (namely, ISO 14001) negatively impacts financial performance.

Whereas a vast number of contributions, as reported above, have focused on understanding the economic returns of innovation and sustainable production choices, such a broad picture of the innovative potential and returns for CE-related technologies is still lacking. Having clarified the need to better understand the economic returns of different innovative practices, it is quite unfortunate not to have such research available for CE-specific technologies. Clearly, environmental technologies and CE-related technologies are deeply connected. CE-related practices and innovations can be intended as signals of firms' attention to corporate social responsibility and sustainability (Reif & Rexhäuser, 2018). EI and technology cover a broader set of activities, that is, all the activities aimed at reducing the environmental impact of firms, including end-of-pipe technologies (Horbach et al., 2012; Horbach & Rammer, 2020). Eco-innovation is a key element driving a transition to a circular economy, but at the same time, it has been stressed that the CE transition is found to be contingent on 'systemic' EI, requiring not only technological changes but also service innovations and novel organizational setups (de Jesus et al., 2018).

de Jesus et al. (2018) highlight that EI and CE are closely related, such that achieving CE without EI is unlikely, but not all EIs are related to CE. Consequently, the impacts of different EIs may be heterogeneous on the different spheres of CE, as also emphasized by Kiefer et al. (2021): Different typologies of EI contribute differently to the various levels of CE (e.g., micro—companies and consumers, etc.; meso—interfirm networks, etc.; macro—province, regions, nations, etc.).

Nevertheless, a better understanding of the EI–CE linkages is needed, and it 'requires, as a precondition, a deeper investigation of the potential drivers of those dimensions of EI that are more relevant for a CE transition' (Cainelli et al., 2020, p. 3) and of those EI characteristics that may spur or hamper a CE transition (Kiefer et al., 2021).

We may expect that increasing policy attention towards a circular economy (European Commission, 2015) and sustainable transition (European Green Deal; Recovery Fund) can create the right incentives for their acceptance and pose the basis for their economic returns. The integration of EI in sustainable and innovative business models, such as circular business models, is complex. The multidimensional aspects that a recent study takes into consideration for the analysis of circular business models (Centobelli et al., 2020) go from contextual factors (environmental factors in which a firm operates) to cross-dimensional practices (practices that favour the transition towards a circular economy, e.g., emerging digital technologies), passing through circular business model dimensions and practices for value creation and value capture (dimension connotating the definition and execution of firms' business model and practices related to the value creation and acquisition of product and processes).

In addition to the abovementioned complexity, which still deserves further investigation, little is known about the economic returns of CE-related technologies. While the main goal of CE is to minimize environmental impacts, namely, in terms of waste and pollution, those technologies are in principle capable of leading to win–win solution, being associated in theory to economic benefits (Geissdoerfer et al., 2017). However, there are yet no systematic empirical studies testing this assumption (as discussed in Demirel & Ozturk, 2019). While the purpose of CE is not per se to spur growth of firms, Horbach and Rammer (2020) conclude that it is important to know whether firms that invest in CE activities will benefit or suffer in terms of their growth prospects and labour demand, motivating the need to study CE economic returns extensively. The two authors consistently analyse, using the German Community Innovation Survey of 2014, whether firms that engage in CE innovations experience positive or negative results in their sales growth and employment. The study finds a confirmation that sales and employment growth have increased in firms having adopted CE-related innovations, especially in lower median quantiles in the growth distribution, and have increased firms' financial standing especially for high-growth firms in the upper quantile. However, the study does not examine the different typologies of CE innovation, as it only focuses on the aggregated category of CE (any-type) adoption. On the latter point, we recall that Ghisetti and Rennings (2014) show that innovation activities that are associated with a reduction in input use (energy or materials) per unit of output lead to short-term profit gains, which may eventually lead to a reduced price per product that may increase its demand. Less clear-cut are the economic returns of other CE activities, such as those associated with a substitution of energy to favour the use of renewables, as this depends on who is producing the renewable energy and its costs for the firm; or to waste reduction or waste recycling or material reuse, as those activities may be costly to the firms whereas by contrast, they cannot outweigh the lower cost of virgin materials.

An unpacking on the economic returns of CE technologies has been proposed in Demirel and Ozturk (2019) on the specific subsample of SMEs. The analysis focused on the effect of CE technologies on firm growth, extending existing evidence on green technologies (e.g., Leoncini et al., 2019; Colombelli et al., 2020) to specific CE technologies. Results suggest a limited capacity of CE to be translated into SMEs firm growth: Only eco-design activities display a positive effect in stimulating growth, whereas water, renewable, energy and water innovations are not affecting SMEs growth.

Overall, a CE transition for a firm will always require costly changes, not only in physical capital (investments) but also in intangibles (R&D activities) and in organizational changes. Flachenecker and Kornejew (2019) focus on a cross-section retrieved from the Community Innovation Survey of 2008 and find support for a correlation between innovations that reduce material use and competitiveness returns for firms that receive public financial support for these activities.

Provided that the research on the relationship between CE-related innovations and firms' economic performance is still scant, we aim to answer the following research questions:

R1. Do CE-related innovations correlate with better economic performance?

What is yet to be ascertained is whether the nature of the innovation itself (product, process or organizational nature) or its type (e.g., energy reduction, raw material reduction and design to promote durability) affects its economic short-term returns. This is what this work tries to shed light on. A recent meta-analysis seem to suggest that differences emerge when distinguishing among process, product or organization 'green' innovations, with organization types found to be the most significant driver for positive firm performance in reviewed studies (Hizarci-Payne et al., 2021).

R2a. Does the relation between CE-related innovations and firms' economic performance depend on the nature of CE innovations (product, process or organizational nature).

R2b. Does the relation between CE-related innovations and firms' economic performance depend on the type of CE innovation (e.g., energy reduction, raw material reduction and design to promote durability).

Finally, we test whether the joint adoption of multiple innovations, that is, bundles of CE-related innovations, shape performance.

R3. Does the adoption of bundles of CE-related innovations correlate more robustly to firms' economic performance than the adoption of single or sparse CE-related innovations?

3 | EMPIRICAL STRATEGY

The empirical analysis draws on original firm-level data from a survey conducted in 2020 by IZI spa for the University of Ferrara on a stratified (size, region and sector) representative sample of more than 4500 manufacturing Italian firms.

Overall, 43% of the firms in the sample declared having introduced at least one of the possible CE innovations listed in Table 1.

Table 1 provides an overview of the distribution of CE-related practices in the representative sample of Italian firms, as already reported in Zoboli et al. (2020). The largest share of CE innovation adopters pertains to the domain of waste, including innovations that allow the reuse of waste into their own or other production processes (23% of firms have adopted such innovations in the period 2017–2019), as well as the domain of energy reduction, including innovations that reduce firms' energy use (23% of adopters). Then, it follows the category of innovations that reduce raw materials (incl. energy), innovations that change the design to minimize energy use or maximize product recyclability and innovations towards renewable energy use. Last come innovations precisely aimed at reducing water use and innovations aimed at abating greenhouse gas emissions (although most of the GHG abatement will be captured by innovations that abate energy use, being energy consumption responsible for most GHG emissions).

TABLE 1 Distribution of CE innovations in the whole sample of respondent firms

CE innovation by	%	Description of the binary variables
Innovation type		
CE_dummy	43	1 if at least one CE innovation is adopted; 0 otherwise
CE_Prod	22	1 if a CE product innovation is adopted; 0 otherwise
CE_Proc	30	1 if a CE process innovation is adopted; 0 otherwise
CE_Org	20	1 if a CE organizational innovation is adopted; 0 otherwise
CE_bundle	16	1 if the firm introduced at least 5 CE innovations; 0 otherwise
Environmental target		
WATER	8	1 if the firm introduced CE innovations to reduce water usage; 0 otherwise
RAWMAT	18	1 if the firm introduced CE innovations to reduce the use of raw materials; 0 otherwise
RENEN	13	1 if the firm introduced CE innovations to increase the usage of renewable energy; 0 otherwise
ENERGY	23	1 if the firm introduced CE innovations to reduce energy consumption; 0 otherwise
WASTE	30	1 if the firm introduced CE innovations to reduce waste; 0 otherwise
WASTE_RE	23	1 if the firm introduced CE innovations to reuse waste; 0 otherwise
ECO_DES	15	1 if the firm introduced CE innovations to change the design in order to increase reparability and recyclability; 0 otherwise
GHG	8	1 if the firm introduced CE innovations to reduce GHG emissions; 0 otherwise

To assess the economic returns associated with CE activities, the original dataset was combined with balance sheet data from the Bureau van Dijk AIDA dataset, leading to a sample loss of one quarter due to missing information. From AIDA information, we extracted the last available year's annual revenues of the firm (2019) and its costs of production (2019). After the merging and the cleaning procedure of extreme values,[1] likely due to some measurement errors or firm-specific conditions (e.g., company liquidation), we end up with approximately 3100 observations, which are still distributed in terms of size, geography and Pavitt sectors (scale intensive, science based, specialized suppliers and supplier dominated) as the original sample.

The two measures of economic performance are more likely than others (e.g., profits) to be affected in the short run by innovations introduced in the 2017–2018 biennium. Moreover, the first variable, revenues, is focused on gains, while the second is on costs, since CE-related innovations may impact both dimensions of the economic performance of the firms, and we aim to single out the relations of CE innovations to the two dimensions considered, revenues and production costs. Indeed, several scenarios may emerge, for example, in the aftermath of CE innovation adoption, increasing revenues may be offset by increasing costs, increasing revenues may be associated with decreasing costs (the best scenario for a firm) or, again, mixed scenarios may be revealed by the analysis.

A first way to empirically assess the potential economic impact of CE strategies is to perform a sample *t* test on group differences on different outcome variables. The *t* test compares the difference in the means of the selected economic log-transformed revenues (revenues per employee) and costs (costs of production per employee) variables of the two groups: One group belongs to those firms having introduced a certain CE innovation, and the other group belongs to those firms that have not introduced such innovations.

The results of the statistical test are reported in Table 2. The statistical analysis allows establishing an association between the outcome variable of interest and the introduction of certain CE-related innovations. It can, however, not allow establishing any direction of causality for such association, and it does not take into account other relevant factors.

As we can appreciate, there is some evidence in favour of a relation between the adoption of CE-related innovations and the two measures of performance, normalized by firm size in terms of employees, leading us to further analyse the relations to provide answers to the research questions posed above.

As *t* tests cannot allow controlling for additional factors, the second step of the analysis consists of testing econometrically for such an association, controlling for variables that may affect it. The following equation is estimated:

$$\text{LnY}_{i,2019} = \beta \text{CE}_{i,2017-2018} + \gamma \text{CONTROLS}_{i,2017-2018} + \lambda + v + e_i,$$

where *i* indexes the 3078 Italian firms; *Y* signals an economic output variable, either revenues (log-transformed) or profits (log-transformed); CE indexes any of the CE-related innovations; λ accounts for four Pavitt-based sectoral dummies; *v* for 21 regional dummies[2]; and ε is the error term. Among the CONTROLS, the following variables

TABLE 2 *t* tests on innovators (EC = 1) and noninnovators (EC = 0)

	Mean EC = 0	Mean EC = 1	Diff: EC = 0–EC = 1	*t* value	*p* value
LnRevenuesEmp					
CE_dummy	11.613	11.736	−.23	−3.2	.002
CE_Prod	11.633	11.79	−.156	−3.4	.001
CE_Proc	11.607	11.797	−.19	−4.65	0
CE_Org	11.665	11.682	−.017	−.35	.719
CE_bundle	11.643	11.8	−.157	−3.05	.003
WATER	11.651	11.854	−.204	−3	.003
RAWMAT	11.648	11.758	−.111	−2.25	.024
RENEN	11.654	11.761	−.107	−1.9	.055
ENERGY	11.630	11.79	−.161	−3.55	.001
WASTE	11.640	11.729	−.088	−2.15	.033
WASTE_RE	11.645	11.744	−.1	−2.2	.026
ECO_DES	11.654	11.754	−.1	−1.85	.068
GHG	11.661	11.76	−.1	−1.4	.164
LnCostsEmp					
CE_dummy	11.618	11.739	−.12	−3.25	.001
CE_Prod	11.616	11.861	−.245	−5.65	0
CE_Proc	11.616	11.791	−.175	−4.45	0
CE_Org	11.664	11.705	−.042	−.9	.357
CE_bundle	11.639	11.834	−.194	−3.95	0
WATER	11.655	11.851	−.196	−3	.003
RAWMAT	11.643	11.793	−.149	−3.2	.002
RENEN	11.654	11.789	−.135	−2.5	.012
ENERGY	11.655	11.726	−.071	−1.65	.1
WASTE	11.637	11.748	−.111	−2.8	.005
WASTE_RE	11.645	11.758	−.113	−2.65	.009
ECO_DES	11.639	11.864	−.225	−4.35	0
GHG	11.653	11.891	−.238	−3.55	.001

TABLE 3 Descriptive statistics of controls and dependent variables

Variable	Obs	Mean	SD	Min	Max	Description
Controls						
GROUP	3078	0.1536712	0.3606919	0	1	Binary variable = 1 if the firm belong to a group; 0 otherwise
EXPORT	3078	0.5204678	0.4996621	0	1	Binary variable = 1 if the firm export part of its products; 0 otherwise
RD_HC	3078	4.88564	13.14379	0	100	Share of employees in R&D activities
SME	3078	0.9850552	0.1213516	0	1	Binary variable = 1 if the firm is a small or medium firm in terms of the number of employees according to the Eurostat definition; 0 otherwise
Regional dummies	\	\	\	0	1	Regional dummies (20) that capture the geographical location of a firm at NUTS2 level
Sector dummies	\	\	\	0	1	Pavitt-based sectors dummies (4): scale intensive; science based; specialized suppliers; supplier dominated
PROD	3078	0.4031839	0.4906168	0	1	Binary variable = 1 if the firm introduced a product innovation in the biennium 2017–2018; 0 otherwise
PROC	3078	0.4353476	0.495883	0	1	Binary variable = 1 if the firm introduced a process innovation in the biennium 2017–2018; 0 otherwise
Dependent variables						
LnRevenuesEmp	3078	11.67	1.07	6.94	14.22	Log of the revenues per employee
LnCostsEmp	3049	11.67	1.01	7.07	14.04	Log of the production costs per employee

are accounted for (Table 3): SME, a dummy taking value one in case the firm is small or medium; GROUP, a dummy that equals one if the firm belongs to a group; EXPORT, a dummy that equals one if the firm undertakes exporting activities; RD_HC, a continuous variable that measures the share of employees in R&D activities; and two dummy variables capturing the introduction of process or product innovations (PROD, PROD).

Tables 4a–4d report the main econometric results obtained by estimating the previous equation by means of robust OLS for both dependent variables considered in this work.

Starting from the first dependent variable—LnRevenuesEmp—we notice that among the controls, GROUP and EXPORT are positively associated with revenues per employee in all specifications (Tables 4a and 4b). In terms of sectors, science-based firms have significantly higher revenues than scale-intensive firms (reference category), while the opposite holds for specialized suppliers and supplier-dominated firms. Moving to the main variables of interest, we observe a specific pattern across the different CE-related variables. Among all of them, only CE-related process innovations are positively associated with higher revenues; the remaining CE-related types of innovations are not (Table 4a). The latter result also holds when we look at the specific typologies of effects targeted by the innovations introduced (Table 4b): They do not lead to any positive or negative short-term return in terms of revenues per employee.

We can answer positively to our second research question (R2b) but only in terms of process innovations. The idea that bundles of CE-related innovations, adopted according to a general strategy of reducing the environmental impact contextually to increase economic performance, is not supported by the evidence, which, however, does not take into consideration potential demand factors that may influence firm revenues.

When we perform the same analysis on the costs of production as the dependent variable, we find the same results as above for the control variables, while the specialized suppliers do not show a worse performance in terms of costs of production with respect to the scale intensity. Moreover, when we focus attention on the variables of interest (Table 4c), we notice again that CE-related process innovation impacts costs, increasing them, and CE-related product innovations have the same impact on costs. Introducing these types of innovations increases the costs of production in the short run because they are likely to require a different production process, potentially new workers recruited to fill internal competence gaps to deal with new products and new processes, new suppliers and/or more expensive intermediate products or materials. The absence of any relation to the cost of production is instead shown when we disaggregate CE-related innovations according to their impact: In this case, only the innovation introduced to reduce GHG emissions, which is somewhat less related to the circular economy concept than others analysed here, is positively associated with the cost of production (Table 4d); new technologies adopted to reduce GHG emissions are likely to increase costs for the sample firms.

Again, for the revenues per employee, for the variable costs, we are able to positively answer the second research question posed above (R2b): The type of CE-related innovation introduced influences the cost of production; in particular, the short-term cost of production seems to rise when CE-related product or process innovations are adopted.

The evidence thus far leads us to consider as almost absent a relation between CE-related innovations and firms' economic

TABLE 4a Dependent variable: LnRevenuesEmp

	(1)	(2)	(3)	(4)	(5)
GROUP	0.411***	0.411***	0.408***	0.412***	0.411***
	(0.052)	(0.053)	(0.052)	(0.052)	(0.052)
EXPORT	0.315***	0.315***	0.312***	0.317***	0.315***
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
RD_HC	0.001	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
SME	−0.051	−0.053	−0.029	−0.064	−0.054
	(0.179)	(0.179)	(0.179)	(0.180)	(0.178)
Science based	0.171*	0.171*	0.178**	0.162*	0.169*
	(0.088)	(0.088)	(0.087)	(0.088)	(0.087)
Specialized suppliers	−0.136**	−0.136**	−0.127**	−0.142**	−0.137**
	(0.058)	(0.058)	(0.058)	(0.058)	(0.058)
Supplier dominated	−0.100**	−0.100**	−0.097**	−0.103**	−0.101**
	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)
PROD	0.060	0.059	0.056	0.068	0.062
	(0.047)	(0.049)	(0.047)	(0.047)	(0.047)
PROC	0.035	0.037	0.015	0.047	0.038
	(0.045)	(0.044)	(0.046)	(0.044)	(0.045)
CE_dummy	0.013				
	(0.040)				
CE_Prod		0.014			
		(0.051)			
CE_Proc			0.084**		
			(0.043)		
CE_Org				−0.066	
				(0.048)	
CE_bundle					0.005
					(0.055)
_cons	12.286***	12.287***	12.222***	12.327***	12.295***
	(0.290)	(0.293)	(0.301)	(0.277)	(0.287)
N	3078	3078	3078	3078	3078
R^2	.082	.082	.083	.082	.082
F	10.452	10.580	10.640	10.643	10.424
df_m	30.000	30.000	30.000	30.000	30.000

Note: Robust standard errors in parentheses; regional dummies included; reference category for Pavitt sectors: scale intensive. No collinearity among the controls: mean VIF = 1.07.
**p* < .10. ***p* < .05. ****p* < .01.

outcomes in terms of revenues and costs,[3] in line with part of the literature on EIs and firms' economic performance. In particular, R1 and R3 do not find a positive answer: The types of CE-related innovation and the adoption of bundles of CE-related innovations are not related to the outcome variables considered here. In addition, we can state that for CE-related process innovations, we are in a scenario in which the increased revenues are ‘counterbalanced’ by the increased costs of production associated with the same type of innovation. This ‘neutral’ (in terms of economic advantages for the firms) short-term scenario may turn positive in the medium-long run, when the production costs do not further increase (in contrast, some efficiency gains may be captured) while revenues do.

Although we are bounded to work with cross-sectional data, with some sensible diachrony between balance sheet data and survey data, it is possible to refine the analysis to capture potential specific relationships between the economic variables and CE-related innovations, as reported in the next subsections.

TABLE 4b Dependent variable: LnRevenuesEmp

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GROUP	0.409***	0.414***	0.411***	0.410***	0.412***	0.411***	0.412***	0.412***
	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
EXPORT	Export	0.316***	0.314***	0.314***	0.316***	0.315***	0.317***	0.315***
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
RD_HC	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
SME	−0.048	−0.060	−0.051	−0.033	−0.059	−0.054	−0.056	−0.056
	(0.178)	(0.179)	(0.179)	(0.179)	(0.179)	(0.179)	(0.178)	(0.177)
Science based	0.167*	0.168*	0.170*	0.174**	0.167*	0.170*	0.166*	0.169*
	(0.088)	(0.088)	(0.088)	(0.087)	(0.088)	(0.088)	(0.087)	(0.087)
Specialized suppliers	−0.132**	−0.139**	−0.136**	−0.134**	−0.139**	−0.136**	−0.138**	−0.137**
	(0.058)	(0.058)	(0.058)	(0.058)	(0.058)	(0.058)	(0.058)	(0.058)
Supplier dominated	−0.098**	−0.102**	−0.101**	−0.100**	−0.102**	−0.100**	−0.101**	−0.101**
	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)
PROD	0.062	0.066	0.061	0.056	0.064	0.062	0.070	0.063
	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)
PROC	0.033	0.042	0.036	0.027	0.040	0.037	0.041	0.039
	(0.045)	(0.045)	(0.044)	(0.045)	(0.044)	(0.044)	(0.044)	(0.045)
WATER	0.058							
	(0.071)							
RAWMAT		−0.028						
		(0.050)						
RENEN			0.031					
			(0.057)					
ENERGY				0.065				
				(0.045)				
WASTE					−0.011			
					(0.042)			
WASTE_RE						0.007		
						(0.046)		
ECO_DES							−0.043	
							(0.059)	
GHG								−0.005
								(0.078)
_cons	12.271***	12.310***	12.285***	12.260***	12.309***	12.292***	12.310***	12.301***
	(0.294)	(0.281)	(0.290)	(0.297)	(0.286)	(0.288)	(0.278)	(0.284)
N	3078	3078	3078	3078	3078	3078	3078	3078
R^2	.082	.082	.082	.082	.082	.082	.082	.082
F	10.390	10.493	10.428	10.569	10.440	10.421	10.501	10.451
df_m	30	30	30	30	30	30	30	30

Note: Robust standard errors in parentheses; regional dummies included; reference category for Pavitt sectors: scale intensive. No collinearity among the controls: mean VIF = 1.07.
$^*p < .10$. $^{**}p < .05$. $^{***}p < .01$.

TABLE 4c Dependent variable: LnCostsEmp

	(1)	(2)	(3)	(4)	(5)
GROUP	0.314***	0.309***	0.310***	0.314***	0.310***
	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)
EXPORT	0.354***	0.350***	0.351***	0.356***	0.354***
	(0.039)	(0.039)	(0.038)	(0.039)	(0.039)
RD_HC	0.002	0.002	0.002	0.002	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
SME	−0.135	−0.119	−0.113	−0.142	−0.129
	(0.164)	(0.164)	(0.164)	(0.163)	(0.163)
Science based	0.192**	0.201**	0.199**	0.186**	0.192**
	(0.080)	(0.079)	(0.080)	(0.080)	(0.079)
Specialized suppliers	−0.073	−0.070	−0.064	−0.077	−0.071
	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)
Supplier dominated	−0.119**	−0.113**	−0.117**	−0.121**	−0.118**
	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)
PROD	0.074	0.049	0.069	0.079*	0.070
	(0.045)	(0.046)	(0.045)	(0.045)	(0.045)
PROC	−0.005	−0.010	−0.024	0.002	−0.010
	(0.043)	(0.042)	(0.043)	(0.042)	(0.042)
CE_dummy	0.010				
	(0.039)				
CE_Prod		0.107**			
		(0.046)			
CE_Proc			0.078*		
			(0.041)		
CE_Org				−0.041	
				(0.046)	
CE_bundle					0.052
					(0.052)
_cons	11.442***	11.418***	11.403***	11.450***	11.442***
	(0.401)	(0.396)	(0.392)	(0.401)	(0.401)
N	3049	3049	3049	3049	3049
R^2	.088	.089	.089	.088	.088
F	11.141	11.506	11.209	11.235	11.317
df_m	30.000	30.000	30.000	30.000	30.000

Note: Robust standard errors in parentheses; regional dummies included; reference category for Pavitt sectors: scale intensive. No collinearity among the controls: mean VIF = 1.07.
$^*p < .10$. $^{**}p < .05$. $^{***}p < .01$.

3.1 | Searching for different relations over different portions of the dependent variable distribution

To deeply delve into the relation between firms' economic performance and CE-related EIs, we look at the results over different quantiles of the dependent variable distributions to search for specific relations in accordance with the firm performance distribution. The simultaneous quantile regressions we settled provide results for three levels of the dependent variable distributions: first quartile (.25), median (.5) and last quartile (.75). In so doing, we can test for the presence of significant differences among the coefficients of the CE-related variables for the first and last quartiles. When the differences are significant, it means that the CE innovations differently relate to the outcome variables according to the portion of the outcome variable distribution we analyse.[4] The simultaneous quantile regressions are based on bootstrapped standard errors, for which we set 150 repetitions, a number of repetitions high enough to maintain quite stable *F* tests we perform to detect differences in the coefficients between the 25th and 75th percentiles of the distribution. In our sample, only

TABLE 4d Dependent variable: LnCostsEmp

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GROUP	0.310***	0.312***	0.313***	0.315***	0.313***	0.313***	0.312***	0.313***
	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)
EXPORT	0.354***	0.354***	0.353***	0.355***	0.354***	0.354***	0.351***	0.354***
	(0.038)	(0.039)	(0.038)	(0.039)	(0.039)	(0.038)	(0.039)	(0.038)
RD_HC	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
SME	−0.128	−0.134	−0.126	−0.149	−0.130	−0.133	−0.137	−0.104
	(0.163)	(0.164)	(0.164)	(0.163)	(0.164)	(0.163)	(0.164)	(0.164)
Science based	0.187**	0.192**	0.192**	0.187**	0.194**	0.197**	0.196**	0.198**
	(0.079)	(0.080)	(0.080)	(0.079)	(0.080)	(0.080)	(0.079)	(0.080)
Specialized suppliers	−0.069	−0.073	−0.072	−0.075	−0.070	−0.067	−0.072	−0.069
	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)
Supplier dominated	−0.117**	−0.119**	−0.120**	−0.120**	−0.118**	−0.116**	−0.119**	−0.117**
	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)
PROD	0.075*	0.073	0.072	0.079*	0.072	0.072	0.060	0.070
	(0.044)	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)	(0.046)	(0.045)
PROC	−0.010	−0.005	−0.009	0.003	−0.007	−0.008	−0.009	−0.013
	(0.042)	(0.042)	(0.042)	(0.042)	(0.043)	(0.043)	(0.042)	(0.042)
WATER	0.078							
	(0.070)							
RAWMAT		0.019						
		(0.049)						
RENEN			0.066					
			(0.054)					
ENERGY				−0.035				
				(0.046)				
WASTE					0.026			
					(0.041)			
WASTE_RE						0.039		
						(0.044)		
ECO_DES							0.088	
							(0.056)	
GHG								0.137*
								(0.073)
_cons	11.438***	11.441***	11.428***	11.456***	11.436***	11.442***	11.439***	11.417***
	(0.401)	(0.401)	(0.397)	(0.401)	(0.400)	(0.401)	(0.397)	(0.402)
N	3049	3049	3049	3049	3049	3049	3049	3049
R^2	.088	.088	.088	.088	.088	.088	.089	.089
F	11.183	11.134	11.098	11.235	11.153	11.152	11.152	11.331
df_m	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000

Note: Robust standard errors in parentheses; regional dummies included; reference category for Pavitt sectors: scale intensive. No collinearity among the controls: mean VIF = 1.07.
*$p < .10$. **$p < .05$. ***$p < .01$.

CE_bundle, ECO_DES and GHG innovation produce coefficients that tend to be significantly different for firms located in the 25th and 75th percentiles of the distribution of revenues per employee. Adopting bundles of CE-related innovations, introducing changes in the product design to increase the durability and recyclability of the product itself and introducing innovation to reduce GHG emissions seem to generate more gains for high-performing firms than for low-performing firms. We can speculate that high-performing firms are likely to be better equipped in terms of financial wealth and workers' competences to enable a quick and full deployment of the activities needed to revise the production process as required by the introduction of complex innovations (eco-design and GHG innovations) or by the introduction of bundles of innovations to start to gain in the short run. The research questions R2b and R3 seem to hold for a limited number of high-performing firms.

In addition to the results of the *F* tests on the simultaneous quantile regressions, we run quantile regressions for each quartile at the 25th and 75th percentiles, which produce the following interesting results (Table 5; only significant results for the 25th and/or 75th percentiles are reported).

CE-related process innovations and those aimed at reusing the waste produced and reducing GHG emissions are linked to 'high-revenue' firms, while for 'low-revenue' firms, CE innovations are not relevant. When we turn to production costs, firms characterized by high production costs positively relate to product innovations, innovation in the design of the product and again in GHG, while for firms with a low level of production cost, many of the CE innovations are significantly positive. In the short run, CE-related innovations seem to 'influence' high-performing firms, both in terms of revenues and in terms of costs (in the latter case, high-performing firms are those with low levels of production costs). Although these results may be confounded by some uncaptured heterogeneity or by some other sources of endogeneity, they nonetheless point to a positive 'impact' of CE-related innovation on firm economic performance in specific regions of the economic variable distributions.

3.2 | SMEs and CE-related innovations

Since most of the firms in our sample, as it is in the population, are constituted by SMEs, we carried out the same analysis as in Tables 4a–4d for this subsample of firms.

The results[5] show that CE-related organizational innovations are negatively linked to revenues, while no other significant impact emerges. In terms of production costs, on the contrary, we register a positive relation with product and process types of innovations and with innovations aiming at reducing GHG emissions and those targeted to increase durability and recyclability through product redesign. Hence, when CE-related innovations are introduced, we do not register a potential short-run positive impact; in contrast, the difficulty of SMEs seems manifestly clear, as these incur a cost increase in the short run without being able to compensate for it through revenue increases.

Similar evidence has been suggested in Arocena et al. (2021), who contend that what they define a 'substantive implementation' of organizational sustainable practices is more likely to occur in large firms and this, in turn, makes such adoption more profitable in large and internationalized firms than in SMEs.

TABLE 5 Quantile regressions for the .25 and .75 quantiles of the outcome variable distributions

	LnRevenuesEmp			LnCostsEmp							
	.75	.75	.75	.25	.25	.25	.25	.25	.75	.75	.75
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CE_Prod				0.093**					0.064*		
				(0.045)					(0.035)		
CE_Proc	0.080*				0.088**						
	(0.041)				(0.037)						
CE_bundle						0.067*					
						(0.040)					
WASTE_RE		0.083**									
		(0.042)									
GHG			0.177*				0.143***			0.176**	
			(0.095)				(0.048)			(0.069)	
RENEN								0.095*			
								(0.052)			
ECO_DES											0.102**
											(0.044)
N	3078			3049							
Pseudo-R^2	.074	.074	.075	.066	.066	.065	.066	.076	.076	.077	.076

Note: Robust standard errors in parentheses; all the controls used for the baseline specifications are included. No collinearity among the controls: mean VIF = 1.07.
*$p < .10$. **$p < .05$. ***$p < .01$.

A further explanation to these results may pertain the (limited) magnitude in the investments towards CE-related activities that SMEs are capable of sustaining and financing. As discussed in Demirel and Ozturk (2019), for CE activities to display an economic return a significant investment has to be undertaken by firms (in their study a threshold of investment to be above 10% of revenues). The lack of funding and the intrinsic uncertainty that characterize any innovation process may limit SMEs investment and consequently the economic returns of CE practices. The necessity to sustain CE-related innovation adoption specifically in SMEs with targeted policies emerges to strongly push the shift towards circular business models in Italian manufacturing firms.

4 | CONCLUSIONS

This work aimed to shed light on the expected economic returns associated with circular economy practices and business models by utilizing a micro firm-level approach. It proposed an empirical analysis based on an original and updated dataset on Italian manufacturing firms that has the advantage, compared to similar existing datasets, of allowing appreciation of the different typologies of CE-related activities a firm may be willing to embrace. As a matter of fact, such a dataset has allowed the current analysis to reveal the economic returns associated with a general category of CE activities, as well as with other specific types of circular innovation and specific environmental targets addressed through such innovations, from energy, materials, to waste and water. This dataset has been combined with balance sheet information from Bureau van Dijk AIDA dataset, allowing us to obtain objective and not self-reported information on the main economic outcomes of interest in the short run: revenues and production costs.

The main findings of the work are that CE-related innovations tend to be scarcely related to revenues and to production costs. CE process innovations are positively associated with revenues, pointing to their potential influence in increasing them, although they are also positively related to production costs together with CE-related product innovations: As firms introduce these types of innovation, they experience production cost increases.

Looking at the quantiles of the performance variable distributions, we obtain some interesting results. Different typologies of CE innovations positively relate to high-performing firms on revenues, while several other typologies of CE innovations positively associate with high-performing firms in terms of production costs (low levels of production costs): In the short run, the firms that introduce CE innovations tend to benefit in terms of revenues but tend to experience a detrimental effect in terms of increased costs of production. The evidence confirms the heterogeneity in circular economy business models and practices already discussed in Zoboli et al. (2020), which translates into different economic impacts.

Finally, when the SME subsample is considered, we mostly find no associations or negative economic impacts from the introduction of CE-related innovations, pointing to the potential difficulties and obstacles SMEs experience in the adoption of circular practices.

The evidence obtained in the present work suggests some policy implications. The gap SMEs face when compared to large firms in getting economic rewards from their sustainable production practices suggests there is room for policies for sustaining the introduction of CE to help them overcoming innovation barriers (as discussed in Ghisetti et al., 2017) which may be specific to the typology of innovation considered, as discussed in García-Quevedo et al. (2020), who also stress that most CE disruptive innovators who redesign goods to reduce materials experience all of the possible existing barriers. Those policies may either be directly aimed at supporting innovation via for instance public funding (Cecere et al., 2020) or public procurement (Ghisetti, 2017) or indirectly aimed at stimulating certain features that facilitate the adoption of CE technologies, such as their internationalization (Chiarvesio et al., 2015), collaboration practices and networking activities with other firms to acquire knowledge from different sources (De Marchi, 2012) or supply-chain integration (di Maria et al., 2022). Such policies, either direct or indirect, are especially needed for SMEs, who are shown in this study to face potential short-term negative impacts through the adoption of CE practices. In terms of managerial implications, the degree of awareness of CE business models should be increased in the managerial staff to generate the capabilities to construct/design profitable circular business models. Since the introduction of single practices (vis a vis a proper circular business model) may be sufficient neither for leading to strong environmental effects nor for improving firms economic performance, by contrast, the short run may even be associated to detrimental economic effects when not properly managed the transition to CE. At the same time, however, it is hard to manage the adoption of multiple (rather than a single) and heterogeneous typologies of CE technologies, as the implementation of a full fledge circular business model require dedicated competences and capabilities, such as 'sustainability oriented capabilities' (Demirel & Kesidou, 2019), and the capability to overcome innovation obstacles that are specific to each of the innovations considered. As a matter of fact, yet most of the firms are found to be unable to translate the concept of circular economy into their corporate strategies, business models and operations, and there is still need to help firms develop the required capabilities. A suggestion may be to stimulate life cycle assessment LCA and R&D spending as those are discussed to be among the most powerful tools to facilitate the sensing, seizing and reconfiguring capacity of new knowledge to identify CE business opportunities and translate them operationally (Khan et al., 2020).

We may argue that an additional obstacle to achieving these policy and managerial goals lies in the yet vague narrative surrounding the concept of a circular economy (and circular economy business models), which does not provide a clear framework for policy makers and managers to design and implement appropriate actions and tools (see on this issue D'Amato & Korhonen, 2021), calling for more holistic approaches of analysis and for further empirical evidence.

The current analysis presents some weaknesses that could not be solved and constitute a limitation for the work. The main weakness is that the empirical analysis cannot make any causal claim; rather, it can only be read in terms of robust associations. Thus far, the current analysis cannot establish whether higher revenues lead to a better capability to invest in R&D and innovative activities and consequently to higher CE-related innovation adoption or, by contrast, whether CE-related activities lead to higher revenues. Furthermore, the dataset, although rich and original, is a cross-section. The time dimension would be very valuable to be explored to better assess when and for how long such economic returns may occur and when, by contrast, they may diminish or vanish. Last, the evidence collected thus far holds for Italian manufacturing firms, and it cannot be extended and generalized to other firms.

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ENDNOTES

[1] We use trimmed values for the performance variables in the subsequent analysis.

[2] The Trentino Alto Adige region is split in its two autonomous provinces: Bolzano and Trento.

[3] We also tried other short-term performance variables, such as returns on sales (ROS), but there is no evidence of significant relations with CE-related innovations.

[4] The regressions results are not reported for space constraints, but they are available from the authors upon request.

[5] The regressions results are not reported for space constraints, but they are available from the authors upon request.

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