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Determinants of eco-innovation in the agricultural machinery sector: the case of small and medium enterprises in the Piedmont region (Italy)

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Abstract
The agricultural machinery industry can significantly contribute to a more sustainable farming system through the development of eco-innovative products and production processes. This is particularly true for small and medium enterprises (SMEs), which represent a significant share of this market. This study investigated the determinants of attitudes towards eco-innovating products and processes in a sample of small and medium agricultural machinery manufacturers ($N=47$) from the Piedmont region (North–West Italy), analysing the role of enterprise's characteristics, perceived drivers and barriers, and environmental concern. Overall, product eco-innovation was considered important/very important for their firms by 88.3% of the respondents, whereas process eco-innovation by 67.7%. The regression analyses showed that the availability of a formal and hierarchical structure dedicated to Research and Development and of financial support were significantly associated ($\beta=0.301$, $p=.032$ and $\beta=0.406$, $p=.011$, respectively) to positive attitudes towards eco-innovating production processes, whereas the lack of know-how was the main obstacle to both product and process eco-innovativeness ($\beta=-0.564$, $p=.000$ and $\beta=-0.397$, $p=.008$, respectively). Environmental concern did not show any significant association with firms' perceived importance to eco-innovate either products ($\beta=0.097$, $p=.475$) or processes ($\beta=0.248$, $p=.087$). Implications for the development of interventions aiming at fostering positive attitudes towards eco-innovation among the targeted enterprises are discussed.

Keywords Eco-innovation drivers · Eco-innovation barriers · SMEs · Manufacturing industry · Agricultural machinery

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1 Introduction

Under the framework of the United Nations (UN) Sustainable Development Goals (SDGs) (United Nations, 2020), agriculture and agri-food systems hold a central position (International Food Policy Research Institute (IFPRI), 2017) and are pivotal to the achievement of the entire set of SDGs (Food and Agriculture Organization of the United Nations (FAO), 2016), particularly in the context of environmental sustainability and development of rural livelihoods (IFPRI, 2017). At the same time, agricultural systems are among the primary producers of greenhouse gases (GHGs) and a major cause of natural resource depletion, water and soil in particular (Golasa et al., 2021). Shifting towards more environmentally sustainable farming systems has then become essential, to face the challenges of the growing food demand of the world population, reduction of waste amount, scarcity of natural resources, and climate change (FAO, 2017).

In fact, during the past decades, the farming sector has been revolutionised by exceptional technological advances, particularly in the farm equipment industry, which has been highly involved in developing the so-called eco-innovations. The term "eco-innovation", also reported in the literature as green or sustainable innovation, was first coined by Fussler and James (1996) referring to a "new product or process which provides customer and business value but significantly decreases environmental impacts". Since then, several studies have been undertaken, defining eco-innovation by its effect on the environment and/or by the intention of the innovator (Rennings, 2000) and improving our understanding of contexts, performance (results and outcomes of eco-innovation), motivations behind the adoption, and process of development or implementation (Diaz-García et al., 2015). More recently, the concept of innovation has also been introduced into the European Union political agenda: in December 2011, the Eco-Innovation Action Plan (EcoAP) was launched as key priority to Europe's future competitiveness, and a new definition was provided, as "any innovation resulting in significant progress towards the goal of sustainable development, by reducing the impacts of our production modes on the environment, enhancing nature's resilience to environmental pressures, or achieving a more efficient and responsible use of natural resources" (European Commission, 2013).

If we consider the agriculture and agri-food context, multinational corporations with dedicated Research and Development (R&D) departments are frequently thought to be the biggest and most significant actors in the eco-innovation process (Touzard et al., 2015; Rotz et al., 2019). However, at the same time, several innovative activities can be observed in SMEs, which often stand out for being more aware of local ecological conditions and locally available growth factors. Moreover, SMEs are more likely to interact directly with end-users, being able of using and enhancing local knowledge to improve their products and services (Stuiver et al., 2004). All this allows SMEs to innovate within the agriculture and agri-food context by being directly connected to farmers' demands (Živojinovića et al., 2020).

Starting from these considerations, the present study aimed to investigate the determinants of firms' perceived importance to eco-innovate their products and production processes in a group of SMEs of the Italian farm machinery and equipment manufacturing sector, by considering the role of firms' characteristics, environmental concern, and perceived drivers and barriers.

In the following section, we will present the state-of-the-art regarding the determinants of firms' attitudes towards eco-innovations, the open issues for the agricultural machinery industry, and the main contributions of the study. Then, the context of the study is

described. Sect. 2 describes the methods adopted (Participants and Procedure, Instruments, and Data Analysis), and Sect. 3 reports the results of the study. Section 4 includes a discussion of obtained results as well as the implications of the findings of the study. In the same section, limitations of the study are also carefully addressed, and areas for further research are pointed out. Finally, Sect. 5 provides the conclusions with a summary of the main findings.

2 Factors affecting firms' attitudes towards eco-innovation: state-of-the-art for the agricultural machinery industry

In the era of "Industry 4.0", agricultural machinery plays a significant role in the sustainability of agribusiness (Miranda et al., 2019; Long et al., 2016), raising a pressing need to look for eco-innovations in this sector. However, some authors (Maçaneiro et al., 2013; Dudek et al.2020) remark on the lack of in-depth empirical investigations in the agricultural context, where innovation systems have their specificity (Touzard et al., 2015). Exploring which factors can influence the farm equipment industry's intention to eco-innovate seems to be highly relevant for understanding the limitations and the potential of agribusiness innovation and enhance business competitiveness and sustainability (Caffaro et al., 2019).

The literature showed that several variables impact firms' attitudes to eco-innovate, which then affects their actual development of eco-innovations (Passaro et al., 2022). Previous studies in other productive sectors (Parker et al., 2009; Cai and Zhou, 2014; Maldonado-Guzmán et al., 2017) showed that the formalisation of the R&D structures enhanced the clarity of the employees' roles and leads to employee commitment and organisational innovativeness (Prakash and Gupta, 2008), whereas it was also noted that innovation is not an exclusive responsibility of R&D function, as it can happen anywhere within the organisation (Braga and Braga, 2013). Regarding the firm's size, on the one hand, some authors showed that the larger the company is, the greater the likelihood the company will move forward towards eco-innovation (Hoogendoorn et al., 2015; Sánchez-Medina et al., 2013). On the other hand, SMEs have been widely acknowledged as a fundamental component of the international modern economies, fostering competitiveness and employment, and developing a strong entrepreneurial spirit of innovation (Organisation for Economic Co-operation and Development (OECD), 2010; Gherghina et al., 2020). This is particularly true with reference to the agricultural machinery industry, where large international corporations are often perceived as the most advanced in innovativeness, but SMEs represent over 98% of agricultural machinery manufacturing enterprises both at European and Italian level (EUROSTAT, 2021).

Considering the role that SMEs are playing as emerging stakeholders in the business and innovation arena (Ragazou et al., 2022), investigating what can promote positive attitudes towards eco-innovation in these firms become key to developing targeted interventions to encourage innovative actions in this population. Furthermore, the previous studies (see for a review Yan et al., 2022) claimed for new research in eco-innovation drivers to provide a differentiated look at SMEs according to the type of industry. Also, research considering SMEs from the manufacturing industry (see for a review de Jesus Pacheco et al., 2017) highlighted the need to differentiate the analysis based also on the type of sector (de Jesus Pacheco et al., 2017).

Finally, even though the increased number of eco-innovations devoted to environmental protection could be attributed to the pressures from international and local institutions,

firms nowadays have a greater awareness of the environmental impact of their activities and are increasingly motivated by environmental concerns in their pursuit of innovation (Saez-Martinez et al., 2014). This may not be the case for the agribusiness sector, since as highlighted by some studies in recent years (Dudeck et al., 2020; Eidt et al., 2020), the predominant model of innovation observed in this sector has not paid enough attention to social and environmental implications. The role played by environmental concern in driving firms and in particular SMEs towards eco-innovations has been completely overlooked in the agricultural machinery manufacturing sector.

Building on the abovementioned state-of-the-art, the present study intends, therefore, to provide a threefold contribution:

- to expand the literature on eco-innovation drivers in SMEs (de Jesus Pacheco et al., 2017; Yan et al., 2022), by addressing SMEs operating in an underinvestigated sector such as the agricultural machinery industry;
- to integrate the literature on the determinants of eco-innovation in agribusiness (Long et al., 2016), by focusing on the determinants of agricultural machinery manufacturing firms' attitudes towards eco-innovation;
- to expand the knowledge on the role played by environmental motivations in affecting firms' perceived importance to eco-innovate (Saez-Martinez et al., 2014), by including environmental concern among the possible determinants of SMEs' attitudes towards eco-innovation.

The final aim of the present study is to identify critical areas for intervention to enhance agricultural machinery manufacturing SMEs' positive attitudes towards eco-innovation, which may then lead to concrete innovation behaviours: indeed, as shown by the previous studies, attitudes towards a certain sustainable behaviour are powerful predictors of the actual adoption of that behaviour (for a meta-analysis, see Klöckner, 2013). Targeted interventions are needed for SMEs, considering that instruments suited for large companies do not necessarily lead to successful outcomes within a SME environment (Bos-Brouwers, 2010).

2.1 Context of the study

Since regional dynamics of eco-innovation represent an important issue (Sanni, 2018) and "eco-innovation is context-specific" (Kemp and Oltra, 2011, p. 252), this study was performed in the specific context of the Piedmont region, which is a particularly relevant area of production for Italian agricultural machinery industry.

Agricultural machines manufactured in Europe meet state-of-the-art standards in terms of safety and ergonomics, environmental protection, and efficiency, reaching the highest technological levels (see cema-agri.org). Moreover, this industry is on the cutting edge in terms of innovation and remains one of the most competitive sectors in the European Union. The European Agricultural Machinery Association (CEMA) represents an industry with 7000 companies spread worldwide, composed of numerous small and medium enterprises (SMEs) and multinationals (Research and Market, 2021) and, in 2018, Europe accounted for 54% of the world's imports and 64% of the world's exports of agricultural machinery, with a net balance of over 4 billion Euros in 2018 (CEMA, 2019). These figures are confirmed by the recent implementation of the AgriTech 2030 plan, that is CEMA's

plan for Europe's Agricultural Machinery Industry aimed at keeping high innovation levels and global leadership.

Within Europe, the Italian agricultural machinery manufacturing sector stands out for being one of the most relevant and competitive at the international level. Indeed, Italy is the second-largest European producer and exporter after Germany, with a turnover of 8.4 billion Euros in 2017 (19% of total EU turnover) and with the highest number of companies, ranging from large global industrial groups to small family businesses machinery (772 companies, accounting for around 25% of European companies, CEMA, 2019). Among the Italian regions, Piedmont (North–West Italy) is one of the main industrial districts, and SMEs represent the major part of the manufacturing industry at the regional level (Istituto Nazionale di Statistica [ISTAT], 2019). In addition, the region has a high degree of industry technology implementation in manufacturing compared to the Italian average, i.e. 11.8% in Piedmont against 8.4% in Italy (Ministero dello Sviluppo Economico [MISE], 2018). According to the latest available statistics (ISTAT, 2020), Piedmont accounts for a total amount of 145 SMEs operating in the agricultural machinery sector, accounting for almost a fifth (19.7%) of the Italian total share (CEMA, 2019; ISTAT, 2019) of companies operating in the farm equipment industry, which could be considered a remarkable number since globally Piedmont comprehends the 7.4% of Italian enterprises. The Province of Cuneo, in particular, is one of the main production areas at the Italian level, with an annual turnover of the agricultural machinery production sector of 250 million euros, approximately 40% of which is achieved on foreign markets (Associazione Revisori Produttori Macchine Agricole [A.R.PRO.M.A.], 2020).

3 Methods

3.1 Participants and procedure

A list of possible participating agricultural machinery manufacturing SMEs headquartered in the Piedmont region was provided by A.R.PRO.M.A., one of the Italian biggest agricultural machinery associations. Possible participants were contacted by phone by the researchers and informed about the aim of the study and the fact that the questionnaire would be anonymous. Those who declared to be willing to participate received the link to the online questionnaire by email. Forty-seven firms, out of the fifty-two reached, accepted to be involved in the study (response rate 90%). The respondent in each firm was either the owner or owner/manager, as these figures were expected to have adequate knowledge and involvement in the decision-making to answer the items concerning their firm operations.

3.2 Instrument

A 25-item online questionnaire was developed based on an earlier national survey on openness to innovation among Italian companies performed by the Italian National Institute of Statistics (ISTAT, 2016) and other previous surveys related to firms' innovation in the Italian and European context (e.g. European Commission, 2014; ISTAT, 2019; Confindustria, 2020). The questionnaire included four sections.

The first section collected background characteristics of the firms, namely staff headcount (indicative of the firm's size) and the level of R&D organisation for the management of innovative projects (European Commission, 2014; ISTAT, 2019). Information

regarding firms' characteristics was collected using short open questions, and the level of R&D organisation was asked by using a multiple-choice question (four possible answers) based on the Eurostat Community Innovation Survey (CIS) (European Commission, 2014).

The second section was designed based on Sanni (2018) and Confindustria (2020), and it was aimed at evaluating the attitude of companies towards introducing product and process eco-innovations which can significantly decrease environmental impacts of both customers and/or firms. Hence, participants were asked to rate on a 4-point scale (from 1 = *not at all* to 4 = *very much*) how important was for their firms to develop two types of product/service eco-innovations (i.e. innovation for the market and within the company) and five types of process eco-innovations (i.e. production process, logistics, production support activities, firm organisation and work organisation) in the next 3 years. These questions were developed following the items used in the CIS innovation survey since it draws from a long tradition of research on innovation (European Commission, 2014).

In the third section, building on the European Commission (2014) and Wang et al. (2023), participants were asked to rate on a 4-point scale (from 1 = *not at all* to 4 = *very much*) the importance of six drivers that may push the firm towards the development of innovations. They had also to rate the importance of different environmental benefits in affecting the decision to innovate (i.e. environmental concern, investigated through six items adapted from previous surveys, see Camera di Commercio Ravenna, 2012; Confindustria, 2020).

In the last section, participants were asked to rate on a 4-point scale (from 1 = *not at all* to 4 = *very much*) the importance of four barriers (based on Walker et al., 2010; European Commission, 2014; Pinget, 2015) for the implementation of innovative activities.

Finally, a standard socio-demographic form for the respondent closed the questionnaire.

The questionnaire required 8/10 minutes to be filled. Prior to being used in this investigation, to guarantee the face validity of the instrument, the questionnaire was pilot-tested, and its items were discussed with two representatives of A.R.PRO.M.A., who had a technical background and were the referents for innovation projects within the association.

3.3 Data analysis

Based on Saunila et al. (2018), two variables were created to represent the respondents' attitudes towards firm process and product/service eco-innovation, by computing the mean of the scores reported for the five items representing process innovation and the two items regarding product innovations, respectively. The same procedure was then used to compute the aggregated scores for the items of the other scales on the questionnaire, namely drivers, environmental concern, and barriers. Cronbach's alphas were then computed to measure the reliability of the aggregated scores. Drivers, barriers, and environmental concern were then used together with the structural characteristics of the firm (i.e. staff headcount and level of R&D organisation to manage innovation) as the independent variables in two multiple regression models computed to investigate the effects of these variables on the attitude towards innovating processes and the attitude towards innovating products. The analyses were performed using IBM SPSS Statistical Package for the Social Sciences v. 26.

The flowchart in Fig. 1 depicts the full procedure adopted to collect data and analyse the results of the survey.

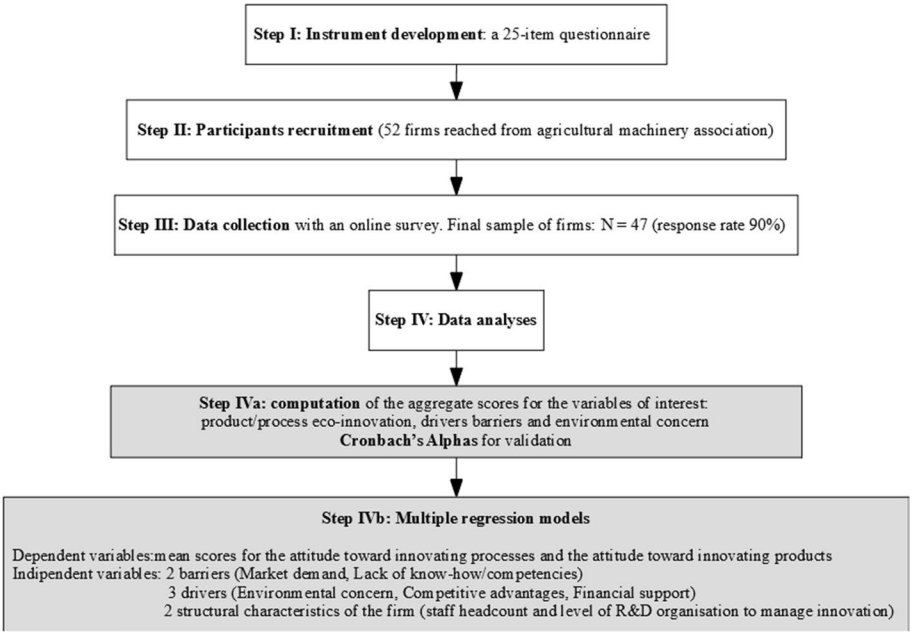

Fig. 1 Flowchart of research procedure and data analysis

4 Results

The main characteristics of the firms involved in the study and of the key respondents for firms are reported in Table 1. Most of the respondents to the survey were the owners of the company (78.8%), mostly men over 50 years old. The great majority of the surveyed firms was represented by small enterprises both in terms of persons employed (89.4% with less than 50 employees) and in terms of turnover (87.2% having a mean turnover of less than 10 million a year). Nevertheless, regarding the level of R&D organisation to manage innovation, almost half of the interviewed firms (46.8%) had among their employees at least one person designated to manage innovation projects though not fully engaged in such activity, while only three of the surveyed firms had a R&D staff exclusively dedicated to innovation projects. On the other hand, 31.9% of the sample firms did not have any form of R&D organisation for innovation project management.

Interviewed key respondents showed considerable interest in introducing eco-innovations in their companies in the next 3 years, especially concerning product innovations. Indeed, as it is shown in Table 2, on a scale from 1 to 4, the mean rating attributed to the importance of this kind of innovation resulted in a score of 3.25. This score is justified by the fact that an overall 88.3% of respondents considered product innovations important (50.0%) or very important (38.3%), in particular when these types of innovations are related to the entire reference sector, and not just limited to the company's context. On the other hand, process innovations received a slightly lower mean score of importance (mean rating = 2.84), even though an overall share of 67.7% of the interviewed companies considered process innovation as important (44.7%) or very important (23.0%) for the next 3 years. In detail, eco-innovation related to the production

Table 1 Main socio-demographic characteristics of the participants and main structural characteristics of the 47 firms taking part in the study, as reported by the respondents

Respondents' characteristics		N	%
Gender	Male	42	89.4
	Female	5	10.6
Age	20–30	5	10.6
	31–40	11	23.4
	41–50	14	29.8
	51 and above	17	36.2
Role in the firm	CEO (owner)	37	78.7
	CEO (shareholder)	6	12.8
	CEO (executive)	4	8.5
Firm's structural characteristics		N	%
Number of employees	< 50	42	89.4
	51–250	5	10.6
Annual turnover	< € 10 M	41	87.2
	€ 11-50 M	6	12.8
Level of R&D organisation to manage innovation	L1	7	14.9
	L2	15	31.9
	L3	22	46.8
	L4	3	6.4

L1 = the company does not have any form of R&D organisation for innovation project management; L2 = the company chooses R&D organisational solutions for innovation project management from time to time; L3 = the innovation projects are entrusted to employees who already hold other positions within the company; and L4 = there is a R&D department within the company and a staff dedicated to innovation projects (source: ISTAT on CIS Survey Questionnaire 2014 model, European Commission, 2014)

Table 2 Mean level (M) and standard deviation (SD) of importance attributed by companies to different categories of eco-innovation to be introduced in the next 3 years and to possible determinants.

Type of innovation	M(SD)	Cronbach's alpha (α)
Product or service eco-innovations	3.25 (0.68)	0.406
Product/service innovative for the market	3.36 (0.64)	
Product/service innovative for the company	3.15 (0.72)	
Process eco-innovations	2.84 (0.85)	0.814
New or significantly improved production process	3.17 (0.76)	
New or significantly improved logistic systems and distribution/supply methods	2.55 (0.83)	
New or significantly improved production support activities	2.98 (0.76)	
New business organisation practices	2.70 (0.85)	
New methods of work organisation	2.81 (0.92)	

The score was assigned based on a 4-point rating scale (from 1 = not important at all to 4 = very important).

process received the highest mean rating of importance (mean rating = 3.17), followed by innovations in other activities supporting production—e.g. maintenance activities, purchasing management, IT systems, administrative and accounting activities (mean rating = 2.98), and by the introduction of new methods to organise individual or teamwork (mean rating = 2.81).

About the items investigating the determinants of firms' attitudes towards innovation, Table 3 reports the mean values for the different items and aggregate scores considered in the study. As can be seen, regarding environmental concern (EC), respondents appeared to value particularly the possibility to save energy, among the environmental benefits which may push towards eco-innovating products and processes (mean rating = 2.57). The possibility to participate in sectorial voluntary agreements on environmental protection was the main driver for the respondents, when considering the possible competitive advantages related to eco-innovation (mean rating = 2.67), whereas the presence of public subsidies was rated as the most important among the possibilities of financial support (mean rating = 2.74). When considering factors which may hinder the development of eco-innovations, our participants rated the unstable market demand and the lack of qualified personnel as the main barriers to making their products and processes greener (mean ratings = 2.19 and 2.57, respectively).

Table 3 Mean level (M), standard deviation (SD), and reliability coefficients of the different items and scales representing firms' perceived innovation determinants

Scales and their items	M(SD)	Cronbach's alpha (α)
Environmental concern (EC)	2.37 (0.17)	0.906
Benefits from pollution reduction	2.48 (0.90)	
Benefits from waste recycling	2.30 (0.97)	
Benefits from adoption of eco-friendly materials	2.37 (0.94)	
Benefits from use of renewable energies	2.43 (0.95)	
Benefits from primary resource saving	2.07 (0.87)	
Benefits from energy saving	2.57 (0.92)	
Competitive advantages (CA)	2.70 (0.12)	0.750
Improvement of social reputation	2.84 (0.81)	
Improvement of competitiveness	2.61 (0.81)	
Sectorial voluntary agreements	2.67 (0.78)	
Financial support (FS)	2.53 (0.18)	0.787
Obtaining external fundings	2.49 (0.95)	
Obtaining public subsidies	2.74 (0.98)	
Availability of internal fundings	2.38 (0.92)	
Market demand (MD)	2.06 (0.17)	0.727
Unstable demand of innovation	2.19 (0.47)	
Scarce demand of innovation	1.94 (0.82)	
Lack of know-how/competencies (LC)	2.21 (0.50)	0.542
Lack of good ideas to innovate	1.85 (0.75)	
Lack of qualified personnel to innovate	2.57 (1.04)	

Table 4 Correlations among the investigated variables

	Staff headcount	Level of R&D organisation	EC	CA	FS	MD	LC	Product eco-innovation	Process eco-innovation
Staff headcount	1.000								
Level of R&D organisation	0.095	1.000							
Environmental concern	0.037	− 0.076	1.000						
Competitive advantages	0.072	0.132	0.221	1.000					
Financial support	− 0.173	− 0.130	0.265	0.251	1.000				
Market demand	− 0.162	− 0.031	-0.042	0.236	0.297*	1.000			
Lack of know-how	− 0.163	− 0.053	0.168	− 0.057	0.317*	0.143	1.000		
Product eco-innovation	0.082	− 0.117	0.037	0.240	− 0.169	0.064	− 0.564**	1.000	
Process eco-innovation	0.103	0.232	0.290*	0.204	0.315*	0.016	-0.195	0.186	1.000

*$p < .05$ and **$p < .01$

Table 4 reports the correlations between drivers, environmental concern, and barriers to eco-innovation and the firm's attitude towards processes and products eco-innovation.

The results of the regression analyses investigating the role of firms' characteristics, drivers, barriers, and environmental concern in affecting firms' perceived importance to eco-innovate their products and processes are shown in Table 5. As concerns the attitude towards product eco-innovation, the analysis reported a significant negative effect of the lack of know-how ($\beta = -0.564$, $p = .000$): the attitude to develop innovative products was hindered by the firms' shortage of specific skills and competencies. Regarding process eco-innovation, the analysis showed a significant effect of the level of organisation within the firm for the management of innovation ($\beta = 0.301$, $p = .032$), the availability of financial incentives ($\beta = 0.406$, $p = .011$), and the lack of know-how ($\beta = -0.397$, $p = .008$). In particular, the positive attitude towards process eco-innovation was higher in those firms in which dedicated R&D personnel are available, and financial support and incentives may be received, whereas the lack of know-how and competencies within the firm appeared to hinder positive attitudes towards innovation.

5 Discussion

The present study intended to provide a contribution to the knowledge of which factors may enable or hinder the development of positive attitudes towards eco-innovations in SMEs belonging to the agricultural machinery manufacturing sector, which plays a pivotal role in promoting a shift towards more sustainable agricultural systems. The results showed that the interviewed SMEs were interested in implementing innovative practices to be more competitive in the market and acquire more advantages. In particular, they rated the development of product eco-innovations in the near future as more relevant compared to process eco-innovations. The level of R&D organisation within firms and the availability of financial incentives significantly supported positive attitudes towards process eco-innovations, whereas the lack of know-how/competencies and the unstable market demand hindered firms' perceived importance of product and process eco-innovations, respectively.

The high level of importance attributed to the development of process and product eco-innovations reported by the interviewed firms is encouraging if we consider that the role of individuals' positive perceptions as key determinants of behaviour is well-known in the literature (Bohner and Dickel, 2011) and documented also for innovation–adoption behaviour (Caron-Fasan et al., 2020). Moreover, the results showed that the interviewed SMEs tended to focus their interest more on product eco-innovation rather than process eco-innovation. This is not surprising, as the previous studies pointed out that product innovation allows dynamic businesses to take advantage of being first to satisfy the needs of consumers and contribute to firms' performance and competitive advantage (Issau et al., 2022). According to Hult et al. (2004), also, product innovation offers a potential protection to a firm from market threats and competitors.

Overall, the present research highlighted two critical aspects that need to be considered to promote the spread of positive attitudes towards eco-innovations also in the underinvestigated agricultural machinery manufacturing sector: the human resources, in terms of know-how acquisition and competencies and the level of R&D organisation for the innovation management within the company, and the availability of adequate financial support (Ghisetti et al., 2015; Silva et al., 2019).

Table 5 Results of the regression analyses on the firms' attitude towards product and process eco-innovation

	Product eco-innovation						Process eco-innovation					
Model	B	B SE	β	R^2	SE	F	B	B SE	β	R^2	SE	F
Constant	3.898	0.446		0.431	0.445	3.505**	1.908	0.537		0.367	0.536	2.680*
Staff headcount	−0.001	0.004	− 0.024				0.006	0.005	0.203			
Level of R&D organisation	−0.113	0.084	− 0.172				0.226	0.101	0.301*			
EC	0.068	0.094	0.097				0.200	0.114	0.248			
CA	0.165	0.121	0.201				−0.091	0.146	− 0.098			
FS	−0.096	0.096	− 0.143				0.310	0.116	0.406*			
MD	0.094	0.092	0.139				0.011	0.111	0.015			
LC	−0.402	0.096	− 0.564***				− 0.324	0.116	− 0.397**			

*$p < .05$, **$p < .01$, and ***$p < .001$

Consistently with the results from Saunila et al. (2018), the environmental concern did not appear to be a possible driver for innovation among the interviewed firms. Indeed, though enterprises are increasingly motivated by environmental concerns to innovate their products and processes (Sáez-Martínez et al., 2014), many SMEs could be sceptical about the environmental benefits deriving from the implementation of technical innovations and prefer waiting for pioneer firms to complete field tests and demonstrate the real performance of such innovations (Biondi et al., 2002). This aspect could be particularly true for agricultural machinery SMEs, which may tend to follow the market demands of farmers, who, in turn, seem to be more likely to use technological solutions on their farms if the possibility of reducing workload, increasing productivity, and reducing costs is guaranteed (Caffaro et al., 2020). Based on this, information campaigns and training activities making farmers aware of the concrete benefits provided by the adoption of these innovations could promote positive perceptions in potential users, which may later spread during informal conversations and then induce demand-pull innovation activities.

The findings of the present study showed that the lack of adequate competencies and skills within the firm, both in terms of shortage of qualified personnel and lack of fundamental know-how to carry on good ideas to innovate, were critical factors for firms' attitudes towards process and product eco-innovation. These findings are in line with a number of studies (see, for instance, Madrid-Guijarro et al., 2009). Indeed, innovation in the manufacturing industry is often connected with the concept of automated processes and the development of digital technologies (Ghobakhloo and Ching, 2019), and the same holds true for the agricultural machinery sector (CEMA, 2019; Miranda et al., 2019). Industrial automation will inevitably eliminate certain low-skilled jobs (Sivathanu and Pillai, 2018); thus, within an eco-innovative manufacturing context, the workforce is expected to possess a new set of skills in the domain of digital technologies and the companies need to have a higher rate of qualified personnel, able to manage more strategic and creative tasks with higher responsibilities (Sjödin et al., 2018). In addition, besides the need to train low-skilled workers, even the skilled employees should be involved in continuing skills development (Kagermann, 2015). In this context, larger firms can more easily focus both on recruiting people with digital competencies and simultaneously developing and empowering digital skills among the existing employees (Sjödin et al., 2018) and implement innovation strategies. Whereas small business managers often lack the types of education and training that have been linked with a successful innovation strategy (Hausman, 2005).

With this regard, Panagiotakopoulos (2011) suggested a series of interventions aimed at stimulating human resource development in small firms to facilitate changes in owners' attitudes and improve access to training interventions. For instance, in terms of changes in owner's attitudes, he suggested the development of an "information counter" to provide "information and empirical evidence to small firm owners around the importance of staff training for small firm survival and success" (p. 16), and the implementation of formal training seminars to increase their awareness of the benefits of entrepreneurs and staff skills and performance development. In addition, other studies (Kotey and Folker, 2007) suggested that e-learning centres could be particularly suited to help SMEs survive and/or integrate into the competitive market.

Concerning the level of R&D organisation to manage innovation, in the present study, it was observed that the higher the level of a company's organisation into a formal structure dedicated to R&D, the more positive the attitude of entrepreneurs to process eco-innovation. This finding could be explained by Schumpeter's two-phase innovation theory (Terziovski, 2010) according to which the innovation process is composed of an "entrepreneurial innovation" phase dedicated to new product development, for which more informal and

flexible structures are necessary, and a "managed innovation" phase aimed to obtain cost efficiencies through process improvement. Both formality and informality are, therefore, important for SMEs' competitiveness. Still, unfortunately, it often happens that only in larger firms, R&D is formally organised in a specific department or unit. In comparison, in most smaller firms, R&D activities are often ad hoc and informal (Griffith et al., 2003). R&D in SMEs is also less likely to be a specialist function than in larger firms, with development work often performed by skilled employees or senior management (Freel, 2005). This situation was well mirrored by the SMEs investigated in the present study since in most cases, they commit innovation projects to employees who already hold other positions within the company or take managerial decisions from time to time.

With regard to the role of the availability of adequate financial support as a driver of process eco-innovation, the results obtained in the present research are consistent with those reported in other studies, considering the financial resources (public and/or external funding) as one of the major factors affecting the growth of firms and the development of eco-innovation in SMEs (Butryumova et al., 2015). Availability of financial support can indeed modify the managers' behaviours and positively affect how they conduct their R&D activities, improving the organisational solutions for innovation project management and increasing collaboration with other partners (Antonioli et al., 2017), and provide opportunities to train skilled personnel to develop sustainable innovation, especially considering the reported lack of competencies for innovation within SMEs in the present study (Biondi et al., 2002).

Moreover, the relationship between financial support and propensity to invest in process eco-innovation could be further explained by the fact that economic incentives to firms, especially external public financing, are often linked to the realisation of specific environmental practices affecting the production process (e.g. saving water, adopting renewable energies, and minimising waste) (Incekara, 2022).

5.1 Implications of the study

The results of the study call attention to the need to implement formal training addressed to the firm's employees. As a matter of fact, the high costs and the duration of training to improve employees' knowledge and skills represent one of the main reasons for manager's resistance to innovation (Madrid-Guijarro et al., 2009); for this reason, informal training is preferred over formal one (Kotey and Folker, 2007). In addition, it was found that often informal training is more reactive to pressing problems within the company rather than to long-term employee development (Roy and Raymond, 2008).

To face this, a number of possible solutions could be implemented to reduce training costs and remain competitive in a complex and changing business environment: "modular" training, i.e. an employee can complete only those chapters of the course that concerns his/her needs or attend training sections that are not well understood, and "personalised" training may be developed according to the needs of each participant (Roy and Raymond, 2008). Regarding the "personalisation" of occupational training programmes, the previous studies set in agricultural and manufacturing sectors (Stuij et al., 2020; Vigoroso et al., 2020) encouraged the adoption of an ergonomic, learner-centred design and underlined the positive effects of a participatory approach in which the workers are proactively engaged in the development of their own training. Moreover, recent events related to the COVID-19 pandemic have sped up the digitalisation of work processes in SMEs (OECD, 2020)

changing the teaching approach and pushing trainees and managers to shift towards online learning methods (Dhawan, 2020).

The study also shed light on the role of SMEs' organisational capability and their difficulties in managing innovative R&D activities in a formal and structured department or unit. In this context, it would be desirable for smaller firms that want to innovate to be less dependent on internal R&D and to aim more at external knowledge acquisition in the scope of "open innovation". With these conditions, leveraging on more flexible and adaptive management and thanks to partnerships with external organisations to generate innovation, SMEs could obtain a competitive advantage over large firms (Gentile-Lüdecke et al., 2019).

The study also calls attention to the system competence and the possibility of effectively accessing public subsidies and funding instruments for SMEs belonging to the agricultural machinery manufacturing sector. To achieve this aim, the role of knowledge-intensive services, such as management and technical consulting, software-related services, and R&D services who actively mediate and interpret the complex system for the firms and facilitate their access to funding policies and instruments, could be considered and promoted. Furthermore, Carbó-Valverde et al. (2016) suggested also that companies that have no access to bank loans during times of financial stress could use trade credit (a business-to-business agreement in which the customer can buy goods or services without paying immediately but paying the supplier at a later scheduled date). Finally, forms of cooperation between firms could reduce costs and share market risks: creating a consortium of enterprises may allow sharing the management costs to obtain higher economic advantages and have more opportunities to access funding (Biondi et al., 2002). As pointed out also by previous evidence, cooperation activities are opportunities to reach complementary technological resources (such as skill sharing), which can contribute to faster development of innovations, improved access to the market and economies of scale, and scope (Antonioli et al., 2017).

5.2 Limitations and future research

Some limitations of the present investigation should be acknowledged. The present results refer to a specific context, the Piedmont region, and were obtained through a non-random sampling procedure, which may limit the generalisability of the research findings to other settings. Anyway, as stated by Kemp and Oltra (2011, p. 252) "eco-innovation is context-specific", and it is usually difficult, if not impossible, to generalise studies from one country to other regions given the great disparities in national innovation systems (Sanni, 2018). With regard to the sample size, the interviewed firms represent about one-third of all the SMEs operating in the agricultural machinery sector in the Piedmont region (ISTAT, 2020), which makes our sample limited in absolute but not relative terms. However, future studies addressing a random probabilistic sample of SMEs also from other Italian regions would be useful to identify strategies and best practices which could be implemented at a national level to promote the innovation of the agricultural machinery manufacturing sector.

Moreover, we cannot say whether innovations or significant enhancements in products and process will actually occur in the surveyed firms in the next 3 years. As our analysis was a cross-sectional analysis based on self-reported data provided by the owner–managers of SMEs, we must rely on the entrepreneur's perceived importance in implementing different types of innovation. In the forthcoming studies, however, it would be interesting

to design a longitudinal study also collecting some objective innovation performance measurements such as the number of new products/processes developed and performance implications such as revenue, profit, and market share, to compare entrepreneur's attitude towards innovation with the actual implementation of innovative activities.

Future developments of the research could focus on SMEs' training needs, which could vary according to business activities but in most cases include teamwork and respect for others, facilitation of meetings, computers and technologies and continuous improvements, time management, health, and safety at work (Roy and Raymond, 2008). Organisational age could also be analysed as a critical variable in determining training needs since older firms employ older managers, who may need to go through skills and knowledge evolution on innovation (Morone and Testa, 2008). Future studies could also explore the relationship between open research strategies and SMEs' involvement in collaborations for innovation and investigate the role of external organisations (e.g. NGOs, universities, and public research institutions, Vigoroso et al., 2023) as contributors to the improvement of firms' innovation performance.

6 Conclusions

The agri-food industry faces challenges related to the growing demand for food, food security control, commercial margins, climate change, environmental protection, and legislation (Miranda et al., 2019). Small and medium firms operating in the agricultural machinery manufacturing sector are, therefore, urged to develop technological innovations to face these challenges to be productive, sustainable, and competitive in the marketplace. In the present study, the availability of adequately qualified human resources, the level of R&D organisation for innovative project management, and the availability of internal and external funding impacted SMEs' attitudes towards process and product eco-innovations. This evidence raises some considerations on the need for small businesses in the investigated sector, to recognise the role of the employees as sources of new ideas and to support the development of appropriate organisational structures and innovation management teams. Furthermore, the present results argue in favour of facilitating access to knowledge-intensive services (e.g. management and technical consulting, software-related services, and R&D services) to promote SMEs' ability to acquire and make use of external financial support in innovation activities. Great opportunities for European SMEs will come from the "NextGenerationEU" plan (European Commission, 2021): it will dedicate funding, equity investment, and business acceleration services to European start-ups and SMEs to reach breakthrough European Green Deal innovation goals (European Commission, 2021) to be scaled up rapidly on global markets emerging stronger from the pandemic, contributing to a more sustainable economy, and creating business opportunities and jobs across Europe.

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Data availability The datasets generated during and analysed during the current study are not publicly available but are available from the corresponding author upon request.

Declarations

Conflict of interest All authors certify that they have no affiliations with or involvement in any organisation or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Ethical approval The study was conducted in accordance with the Declaration of Helsinki and approved by the Research Advisory Group of Institute for Agricultural and Earthmoving Machines (now denominated Institute of Sciences and Technologies for Sustainable Energy and Mobility) of the National Research Council of Italy (date of approval: 29 September 2020).

Informed consent Informed consent was obtained from all subjects involved in the study.

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