Volume 32 Issue 10, December 2025
1366-2716 (Print)

Industry and Innovation

Routledge
Taylor & Francis Group

Industry and Innovation

ISSN: 1366-2716 (Print) 1469-8390 (Online) Journal homepage: www.tandfonline.com/journals/ciai20

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To cite this article: Davide Antonioli, Claudia Ghisetti, Massimiliano Mazzanti, Francesco Nicolli & Marco Quatrosi (2025) "Twin transition" and HRM practices: empirical evidence from Italian firms, Industry and Innovation, 32:10, 1184-1203, DOI: 10.1080/13662716.2025.2516036

To link to this article: https://doi.org/10.1080/13662716.2025.2516036

Published online: 28 Jul 2025.

INDUSTRY AND INNOVATION
2025, VOL. 32, NO. 10, 1184–1203
https://doi.org/10.1080/13662716.2025.2516036

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RESEARCH ARTICLE

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"Twin transition" and HRM practices: empirical evidence from Italian firms

Davide Antonioli[a], Claudia Ghisetti[b], Massimiliano Mazzanti[a], Francesco Nicolli[a] and Marco Quatrosi[c]

[a]Department of Economics and Management, University of Ferrara, Ferrara, Italy; [b]Department Sociology and Social Research, University of Milan - Bicocca, Milan, Italy; [c]Department of Law, University of Palermo, Palermo, Italy

ABSTRACT

The increasing policy emphasis on achieving a joint green and digital transformation – referred to as the 'twin transition' is driving techno-organisational change in new directions. This paper examines how firms' internal organisation of labour in the manufacturing sector influences their ability to innovate in the interconnected green and digital domains. Given the systemic nature of sustainability transitions, its 'twin' evolution introduces complexities that extend beyond the challenges posed by decarbonisation and circularity. Empirical results show that organisational changes and human resource practices, alongside technological advancements, play a pivotal role in facilitating this transition.

KEYWORDS

Twin transition; organizational set-ups; Eco-innovation; industry 4.0; technological innovation

KEYWORDS

O30; Q53; Q55; R11

1. Introduction

After the spread of the COVID-19 pandemic, the European Union launched a set of major policy initiatives and massive investments to guide the recovery. Among those actions, the European Union's (EU) 2020 Industrial Strategy, explicitly sets the desirable direction for EU to be globally competitive, climate-neutral, and digitalised, calling for the need to combine environmental (henceforth green) and digital transformations—the so-called 'twin' transition (European Commission 2020a, 2020b). The call for the EU to embrace a 'twin' transition also emerges in other major initiatives, such as in the European Green Deal, in the European Digital Strategy—which aims to enhance the global competitiveness of the EU's digital ecosystem while pursuing environmental goals—and in the Next Generation EU, to mention the main ones.

Firms are thus facing multifaceted challenges coming from the current competitive environment and policy agenda. Among other targets, they need to innovate on 'traditional' forms of innovation (e.g. product and process), they need to adapt to emerging environmental challenges and potentially be pro-active innovators to meet increasing environmental targets and they are asked to embrace a digital transformation. This paper starts from the recognition that the complexity of the transformations at stake, including the 'twin' one, requires firms to possess not only technological competences but also the capacity to sustain the technological changes and the persistent innovation activities, over different dimensions, through the adoption of appropriate organisational practices (settings).

The work mostly bridges the literature concerning innovation determinants, whose contributions are flourishing and abundant, with the one related to the firm's organisational capabilities (e.g. Chiva et al. 2007; Presenza et al. 2017). The latter concerns several dimensions of the organisational structure, ranging from the types of knowledge sourcing adopted by the firm to the absorptive capacity provided by the human capital at the firm disposal. We mainly focus on organisational capabilities related to the employees and the organisation of labour at firm level such as the employee's involvement, their training and their performance evaluation and study how those affect the 'twin transition'. The Human Resource Management (HRM) practices just mentioned, which constitute a part of the overall firm organisation of labour and production, assume in this work a privileged position in the analysis of the factors affecting the firm's capacity to exploit the opportunities and managing the threats brought by the 'twin transition'. More specifically and given the scope of the present work, we maintain that HRM practices may influence the

CONTACT Claudia Ghisetti Claudia.ghisetti@unimib.it Department Sociology and Social Research, University of Milan - Bicocca, Via Bicocca Degli Arcimboldi, 8, Milan 20126, Italy

firm's capacity to adopt innovations, including green and digital ones. Each firm's endeavour towards a reconfiguration of its organisation, resources and capabilities to react, but also proactively influence, the green and digital transitions pass through the change of its human capital, and HRM practices critically influence such a change.

One of the main original objectives of this paper is, in line with Carboni and Russu (2018), to shed further light on the complex relation at firm level on product, process (Hullova, Trott, and Simms 2016) and organisational/human resource management practices (Bloom and Van Reenen 2007), given the potential prominent role of the latter in designing the ground over which innovation flourish or struggle to come to light.

On the other hand, existing studies have not yet been extended to scrutinise the contribution of HRM practices to the 'twin' transition, and this constitutes the second original contribution of this work. In analysing these set of linkages, we add to the existing literature a perspective on specific typologies of innovation practices, providing for the first time, at the best of our knowledge, evidence of original relations between organisational practices and the 'twin' transition. We focus on 'twin' innovation practices when firms jointly undertake innovations leading to environmental benefits (environmental innovations, green practices henceforth) with digital practices.

The paper focuses on a large country like Italy which still present one of the key manufacturing systems worldwide. Though GDP growth has languished over the last 24 years, today the country ranks 9th in terms of nominal GDP and 13th in PPP terms. The manufacturing system still drives a positive current account balance and net imports have maintained a positive figure over the past decades. Notwithstanding stagnating investments in R&D, which are still far from European targets, Eco-innovation performances (DG RTD Innovation Scoreboard) are instead remarkable. Against this background, the joint investment in green and digital innovation and knowledge may serve future economic development in the country, possibly allowing it to compensate certain structural deficits.

Section 2 positions the paper with respect to existing literature and it postulates the main research aims, Section 3 provides a description of the original dataset at our disposal and the methodology and variables construction, while Section 4 discusses the main results and Section 5 outlines policy and managerial implications that can be drawn.

2. Research aims

To shed light on the main objective of the work, we need to control for the main elements affecting firms' choices towards 'twin' practices. Whereas the literature on the drivers of digital practices using firm level data is still in its infancy,[1] since the seminal contribution by Rennings (2000) (for a review, Barbieri et al. 2016) we can draw on abundant literature on environmental innovation determinants, namely focusing on what drives the adoption of innovations resulting in a reduction of the environmental impacts associated to the production of products and/or production processes. Building on this literature, and its extension on so called circular economy innovations (Horbach and Rammer 2020), whose drivers are comparable (see Cainelli, D'Amato, and Mazzanti 2020), we selected our main control variables.

According to the relevant literature (e.g. Horbach 2008; Horbach, Rammer, and Rennings 2012; Rennings 2000) the main determinants can be grouped into: Market-pull (market conditions such as expectations of future turnover, previous economic performance, demand for new eco-products or consumer preferences); Technology-push (pertaining the knowledge-capital endowment, stimulated for instance by R&D activities and personnel); Regulation (i.e. any relevant policy that directs firms innovative activities towards a reduction in their environmental impacts, including either hard or soft measures) and a residual group of determinants pertaining firm-specific factors (such as firm size, location, internationalisation and organisational setting).

[1]An exception is the literature on the emergence of patenting activities in digital technologies (OECD 2019). However, such literature is mostly either at the patent level or at an aggerate level, and it cannot be easily extended to the context under scrutiny. Such literature provides interesting evidence: digital technologies distribute unevenly across countries, regions and sectors (Ciffolilli and Muscio 2018; Martinelli et al. 2021) and their diffusion of digital technologies lead to the emergence of new technological 'leaders', not previously advanced in ICT (Balland and Boschma 2021; Capello and Lenzi 2021).

This work enlarges the fourth group of determinants, i.e. firms specific factors, and it assesses whether certain organisational settings, which are firm specific, favour or not 'twin' production choices.

We focus on HRM as one strategic business area related to human capital and capacity-building within a firm. A proper HRM design provides suitable means to align job demands and competencies of workers and offers sufficient criteria for assigning tasks to certain categories of workers that can be widely applied in the work environment (Marsden 1999).

Indeed, according to Teece (1996, 2007) formal and informal organisational structures impact on the firm's innovation activity and dynamic capabilities are at the core of the firm's capacity do develop and maintains sustainable competitive advantages, through the capacity of managing threats and exploit opportunities. Although the dynamic capabilities mainly reside in the top management team (Teece 2007), it is also the structure and the organisational processes of the firms, to impact such capabilities and in the words by Teece, Pisano, and Shuen (1997), the dynamics capabilities shape 'the firm's ability to integrate, build and reconfigure internal and external competences to address rapidly changing environment' (p. 516). Hence, we can argue that the development and accumulation of firm-specific competences in the overall organisation may result in distinctive, not-easy to imitate and difficult to replicate capabilities that make some firms more receptive than others towards the opportunities and better equipped than others to cope with the threats brought by the 'twin transition'. As shown by Khan, Daddi, and Iraldo (2020) and Seles et al. (2022), dynamic capabilities may be considered as enablers of the circular transition as well as they are potential building blocks at the basis of a firm's digital transformation (Ellström et al. 2021). As the latter study underlines, the dynamic capabilities are elusive and difficult to be empirically measured, we focus on a specific 'bite' of the overall dynamic capabilities: the HRM system of each firm. This is constituted by a complementary and interdependent set of practices (Lado and Wilson 1994) that can generate those competences and skills, which ultimately represent distinctive and not imitable (at least in the short run) traits of the firm's human capital that create competitive advantages and shape the absorptive capacity of the firm.

Recently, it has been shown that HRM practices (e.g. training, quality management system, teamwork and interfirm relations) together with the adoption of environmental practices affect employee performances and allow to access different sources of knowledge (Delmas and Pekovic 2018). Orienting organisational practices to include environmental concerns, for instance through Green Human Resource Management (GRHM) or Circular Human Resource Management (CHRM), provides a suitable framework for environmental practices adoption and diffusion (Daily and Huang 2001; Dibia et al. 2020; Parida, Brown, and A C. Di 2021; Renwick, Redman, and Maguire 2013; Sidique and Pereira 2023; Tariq, Jan, and Ahmad 2016). Changes in HRM practices to improve training, communication among employees and self-efficacy are proved to be associated to the introduction of environmental standards (Balzarova et al. 2006; Delmas and Pekovic 2013; Sammalisto and Brorson 2008). Furthermore, reforms of HRM increase the probability to adopt environmental management practices (Grolleau, Mzoughi, and Thomas 2007). The joint implementation of Industry 4.0 and Circular Economy practices improve the sustainable production of enterprises, with Circular Economy tools that may assume the role of mediating factors in the relationship between Industry 4.0 and sustainable production (Cuevas-Pichardo et al. 2024).

Conversely to the abundant literature above mentioned, the literature on the relation between HRM practices and environmental innovations is less developed. Hottenrott, Rexhäuser, and Veugelers (2016) highlight the importance of organisational changes as complementary practices to environmental technological innovation to productivity gains. HRM practices improve skills and self-efficacy of employees, fostering their green-innovative capabilities (Peng et al. 2024). Similarly, but in a study not involving the economic performance of the firms, Antonioli, Mancinelli, and Mazzanti (2013) analyse the complementary relation among different organisational practices and environmental innovation, as output variable. More green-focused HRM practices have been found to foster green innovations (Ahmed, Mozammel, and Zaman 2021; Labella et al. 2022; Song, Yu, and Xu 2021). In the context of circular economy, the adoption of non-technological innovative practices, such as CHRM, are proved to be fundamental to stimulate technological circular innovations (Castro-Lopez et al. 2025).

Moving from GREEN to DIGITAL practices, the literature on the relationship between Industry 4.0, capacity-building, and human resources has grown in the last couple of years (Ammirato et al. 2023). In the digital transition, the human component is crucial to foster the integration between physical and virtual

assets (Longo, Nicoletti, and Padovano 2017). Indeed, when adopting the Industry 4.0 framework within the production processes, workers' skills should be developed and therefore human capital should be increased within enterprises (Fantini, Pinzone, and Taisch 2020). Furthermore, focusing on human resources among other factors, is crucial to include Industry 4.0 within the sustainable manufacturing framework (Bag et al. 2021; Dabić et al. 2023; Rehman et al. 2023). Organizations and in particular HRM should become more proactive and involve management in fostering strategic change (Dhanpat et al. 2020; Imperatori et al. 2019). HRM oriented to social responsibility is able to overcome all the human-related barriers to Industry 4.0 such as resistance to change, reskilling, organisational culture (Hansen, Christiansen, and Lassen 2024; Kipper et al. 2021; Mukhuty, Upadhyay, and Rothwell 2022; Piwowar-Sulej 2021; Whysall, Owtram, and Brittain 2019). Especially in manufacturing enterprises, organisational changes aimed at interactively involving employees and participatory design processes support the engagement of workers in the implementation of Industry 4.0 (Kaasinen et al. 2020). 'Industry 4.0' technologies, tend to be accompanied by organisational changes (Timothy et al. 2002) including computerisation, workplace organisation, increased demand for skilled workers and training. Recent evidence confirms that digitalisation is accompanied by skills upgrading and learning (Cirillo et al. 2023a).

HRM practices such as training, evaluation of performances and hiring are proved to increase capabilities and knowledge sharing among employees. This, coupled with a higher level of involvement implied using specific practices (e.g. shared information on the firm's strategic objectives), empower the employees, improve their motivation knowledge basis and ultimately their performance (e.g. Cappelli and Neumark 2001; Ichniowski and Shaw 2003). Arguably, the augmented innovative capabilities can orient the adoption of either digital or green technologies. With respect to the previous streams of analysis, we add to both the newness of perspective on 'twin practices' and the original and rich information at our disposal on organisational set-ups with a large set of HRM practices, specifically detected by a unique questionnaire administered to a representative sample of Italian firms for the period 2017–2020. Works on the relationship between HRM and environmental practices, mostly focus on the role of organisational capabilities to foster environmental management. In this work, we focus on the role of HRM to foster both green and digital-oriented innovation. Furthermore, while most of the literature on organisational capabilities and digital transition is related to aspects of training and recruitment of employees, in this study we expand the framework including other HRM areas, such as evaluation of performances and communication to employees.

The main research questions are:

(1) What are the areas of HRM, namely training, evaluation of performances and communication to employees, that play a fundamental role in fostering twin practices?
(2) Do those areas of HRM differently relate to green and digital practices?

In answering these questions, we intend to provide meaningful implications about what we conceive to be a current and future crucial issue in the diffusion of circular business models: the relation between HRM and 'twin' practices.

3. Empirical analysis

3.1. Dataset

The dataset for the empirical analysis is composed of the two waves of a survey on manufacturing enterprises in Italy. The surveys have been conducted in 2020 and 2021 at national level on those manufacturing companies with at least 10 employees, by the company Izi. Both the waves were configured as a CAWI (Computer Assisted Web Interview) survey through which a structured questionnaire was administered to companies. This questionnaire is made up of 4 main macro-sections: Business Characteristics; Innovation and Investment; Environmental Performances; Organization, Training and Industrial Relations. Within each section, an appropriate set of questions allows for the collection of relevant information on the various themes. To have a representative sample of Italian firms, in each wave about 4600 responding companies were randomly selected after a stratification along the following

three dimensions: geographical location (macro-area, ISTAT), sector (technological intensity, Eurostat), size (10–49 employees; 50–249 employees; 250+ employees).

The first wave covers the two-year period 2017–2018, an economic growth period, whereas the second wave 2019–2020, an economic slowdown period. The dataset used is an unbalanced panel of 8952 firms. Companies that were surveyed in both waves were only 2196. To avoid a statistical loss, the main analysis is performed on the unbalance panel.

3.2. Measuring 'twin' practices and organizational set-ups

Our main variable of interest, *TWIN*, combines digital practices undertaken by firms who benefited from Industry 4.0 Italian national plan (*DIGIT*) with the adoption of environmental innovations leading to a reduction of environmental impacts under multiple dimensions (*GREEN*). *TWIN*, in particular, takes a value of 1 if the firm has adopted any environmental innovation and benefited from the Industry 4.0 programme.

Starting from the first element, *GREEN*, the implementation of environmental innovations has been investigated from the set of questions on adoptions of different practices leading to a reduction of the company's environmental footprint. The questionnaire is mostly focused on environmental innovations pertaining the circular economy paradigm, and include innovations leading to material (including energy, electricity and water) reduction, waste reuse, waste reduction, waste transfer to other companies in order to be used in their production process, and changes in product design to either reduce material inputs or maximise recycling. Additionally, the questionnaire includes other types of innovation that more broadly lead to environmental benefits without belonging to the circular economy paradigm, such as innovations leading to the reduction of atmospheric emissions, energy efficiency and consumption from renewable sources. Overall, a company has adopted an environmental innovation if it has introduced at least one of the abovementioned innovations. In other terms, *GREEN* equals 1 for firms who adopted one or more environmental practice in the period surveyed. In our sample, *GREEN* takes value one in 39.6% of the cases: 3571 out of 8952 firms have adopted at least one typology of innovation leading to environmental benefit.

Moving to the second element used in constructing the dependent variable, *DIGIT* assigns value 1 to firms that have benefitted from at least one of the incentives outlined in the Italian Industry 4.0 programmes. This signals that those firms have undertaken a certain digitalisation practice (at different degrees). In particular, the Italian Industry 4.0 paradigm encompasses the progressive digitisation of production and business operations through sensor-based devices, Internet of Things (IoT), ICT infrastructure, Big Data analytics. A company has benefited from the Industry 4.0 paradigm, if it has introduced changes towards more digitised business operations. Ideally, Industry 4.0 plan promoted a more efficient use of resources and a more informed decision making through smart manufacturing, real-time monitoring, sensor-based devices and Big Data. The paradigm comprehends the progressive digitisation of business processes and operations. This includes changes in the production process beyond linear manufacturing (e.g. cloud manufacturing, additive manufacturing). On the other hand, Industry 4.0 encompasses also all the implementations related to the ICT infrastructure of a company (e.g. cybersecurity, Big Data Analytics). Therefore, those companies in the sample that have adopted any implementation within the framework of Industry 4.0 have either implemented changes to the production process or to business operations in general, with very heterogeneous degrees of digitalisation. In our sample, *DIGIT* takes value one in the 22% of the cases: 2022 out of 8952 firms benefited from the Industry 4.0 national plan.

Contrarily to *GREEN*, which specifically measures *adopted* innovations in that realm, *DIGIT* is a proxy of digital practices that the firm may have undertaken thanks to the program Industry 4.0: the firm is not self-reporting to have adopted digital innovations, but it is self-reporting to have benefited from a digitalisation program. For this reason, we refer to 'practices' rather than 'innovations' as we cannot ascertain the nature of the practices undertaken in response to the program; these may be adopted innovations or not necessarily innovations.

One may argue that DIGIT is a policy treatment variable that may lead to a selection bias. However, the program was not designed to benefit only certain categories of firms: Industry 4.0 was intended to support the digitalisation of firms across all sectors. Moreover, since all eligible firms that applied for support

received it, the policy design helps mitigate the risk of bias due to explicit ex-ante selection of beneficiaries by policymakers (Cirillo et al. 2023a, 2023b; Italian Ministry of Economic Development 2016).

Nevertheless, firms may still self-select into the 'treatment' during the application process, based on both observable and unobservable factors. We cannot control for this in this study, and it remains one of its key limitations. However, we maintain that this does not substantially affect our results, as our objective is not to estimate the policy's effect. Instead, we exploit this variable to extract information on firms' digitalisation efforts. Given that this is the main goal of the analysis, we argue that program participation serves as a good – yet imperfect – proxy for capturing firms' digital transformation.

Table 1 shows the distribution of the variable *DIGIT* considering the sectoral technological intensity a firm belongs to, and it shows a quite balanced distribution of digital practices across different technological levels.

Moving back to the core variable, *TWIN* takes value one in the 13.6% of the cases: 1230 out of 8952 firms experience, with their organisation, combinatorial environmental and digital practices.[2]

Table 2 shows the joint distribution of the different types of environmental innovations and *DIGIT*, showing that material, energy and waste reduction are the environmental categories showing the highest

Table 1. Tabulation of sectoral aggregation and Industry 4.0 plan.

		DIGIT	
	Firms in the sector	0	1
Medium-High-Tech	19%	74%	26%
Medium-Low-Tech	35%	74%	26%
Low-Tech	46%	81%	19%

Table 2. Cross tabulation of digital practices across different green innovations.

		DIGIT	
Green innovation type:		0	1
Water Reduction	0	73%	20%
	1	5%	3%
Material Reduction	0	67%	16%
	1	10%	6%
Energy use from renewable sources	0	70%	18%
	1	8%	5%
Electricity Reduction	0	65%	15%
	1	12%	8%
Reduction of waste generated	0	67%	17%
	1	11%	6%
Reduction of waste generated (Product)	0	71%	18%
	1	7%	4%
Waste Disposal	0	67%	18%
	1	10%	5%
Design of the product to minimize material consumption	0	71%	19%
	1	6%	4%
Design of the product to increase recycling potential	0	73%	19%
	1	5%	3%
Emission reduction	0	74%	20%
	1	4%	3%
GREEN (Any of the above)	0	51%	9%
	1	26%	14%

[2]Given the possible self-selection of firms into Industry 4.0, it would be helpful to compare this statistic with an external one. The only available statistics we found comes from the recent European Investment Bank Investment Survey (EIB 2021) on European firm's investments in green and digital technologies, in which 30% of European firms have declared to have planned to invest in both green and digital (thus 'twin') technologies. The European average of 'twin' practices doubles the Italian one, but we cannot know if this is due to i) the different perspectives: we look at adopted practices, EIBS looks at foreseen investments thus being more extensive, ii) to the presence of an Italian lag with respect to European average firms, iii) a problem of self-selection in our DIGIT components or iv) a combination of the above. Moving to Italian evidence, the share is lower than the about 39% of firms having declared to have invested in the Longitudinal Survey of Businesses and Work run by the Italian National Institute for the Analysis of Public Policies discussed in (Cirillo et al. 2023a, 2023b).

probability to be twined. However, environmental innovations are not self-excluding categories: in our sample it is very likely that a firm is embracing jointly more than one environmental innovation.

We hereby give an extensive interpretation of the 'twinning' of green and digital transformation, without imposing it to occur at the product or at the technology level, but rather accepting that a firm that (even in different operations) combines certain digital practices with certain green practices is operating a 'twin' transformation. This is not uncommon in the emerging literature on the twin transition. Bianchini, Damioli, and Ghisetti (2023) focus on an aggregate level of analysis and consider 'twin' regions as those capable of combining digital with environmental technologies. They suggest that the twinning of digital and green practices hardly occurs at the technology level, observing that less than 1% of European patent applications are both green and digital: their technological content tends to be distant. Montresor and Vezzani (2022) draw on data from an Italian survey to show that firms' investments in AI support their ability to adopt environmental innovations, without forcing AI investments to be associated to specific innovations.

Moving to the main explanatory variables, the questionnaire offers a large number of organisational practices whose implementation and frequency within the firms are asked to the respondents (Table A1 in Appendix A1). Thanks to this articulated set of organisational practices, ranging from recruitment practices to employees involvement, we are able to capture different dimensions of the organisational capabilities each firm has.

For the relevant explanatory variables on organisational settings a set of 18 questions has been selected from the dataset dealing with the implementation of human resource management practices for recruitment, employee communication and involvement in the life of the company, performance evaluation and incentive-based payment practices. Principal Component Analysis (PCA) has been applied to this set of variables to provide a more synthesised measure on organisational setting changes (see Table A1 for the full list). Considering the nature of the variables, the PCA algorithm has been run on the matrix of polychoric correlations among the variables. After the PCA, the 18 questions have been reduced to 3 Principal Components providing information on the relevant HRM practices subject to this analysis. Table 3 shows the components generated from the set of questions.

The analysis identified three specific areas of HRM reforms through the emergence of the following three components (details in Appendix A2; scree plot presented in Figure A1).

EMPL_INVOLV, employees involvement, is the component related to communication and involvement of employees on critical aspects of the life of the company – as reported by a broad literature employees involvement may have a positive impact on the firm performance (e.g. Black and Lynch 2001; Caroli and Van Reenen 2001), but it may also influence the innovation adoption (Uhlaner et al. 2013; Van Wijk, Jansen, and Lyles 2008).

EVAL_PERF, evaluation and pay performance is the component representing the set of questions assessing the implementation of performance evaluation mechanisms and incentive-based payment methods – these practices are directly linked to higher employees' performance (Damiani and Ricci 2011; Lucifora and Origo 2015), which in turn (and in a dynamic perspective), through an indirect effect given by high economic performance and investments may increase the capacity to innovate of the firm.

RECR_TRAIN, recruitment and training, is the component related to the implementation of changes in the recruitment and training of (new) employees. The set of practices mainly explained by this component is related to the absorptive capacity of the firm, which is at the basis of the firm's learning processes, and crucially shapes the ability of the organisation to exploit external knowledge and (new) technologies (Presenza et al. 2017) as well as to increase the capability to experiment, take risks, to set up participative decision making (Chiva et al. 2007).

We also constructed and tested a dichotomised version of the three organisational practices variables. Guided by the results of the PCA in the selection of the relevant items pertaining each dimension (as in Table 3) *EMPL_INVOLV (dummy)* takes value 1 if one or more of the practices related to this dimension is adopted by the firm and zero otherwise. Looking at its descriptives, 76% of the firms adopt organisational practices that favour employee involvement. *EVAL_PERF (dummy)* takes value 1 if one or more of the practices related evaluation and pay performance is adopted by the firm and zero otherwise. Looking at its descriptives, 53% of the firms in the sample implement performance evaluation mechanisms and incentive-based payment methods.

Table 3. Loadings of the Principal component analysis on organizational practices.

Question	Principal components – Varimax rotation		
Recruitment and training			
Candidates upon hiring undergo structured interviews (questions related to the job, standardized for every candidate with objective measurement scale)	0.207	0.196	**0.779**
Candidates upon hiring undergo formal tests (written test or simulations of problem solving of real cases)	0.151	0.279	**0.744**
Employees receive professional training	0.417	0.191	**0.668**
Results of performance evaluation are used to determine training needs of employees	0.339	0.249	**0.694**
Employees are refunded for external training courses	0.297	0.32	**0.547**
Evaluation and pay for performance			
Employees receive formal evaluation of their performances	0.318	**0.479**	0.499
Raises of salaries are based on employees' performances	0.323	**0.632**	0.351
Employees receive bonuses, rewards linked to productivity, individual performances or other indicators	0.262	**0.812**	0.27
Employees receive bonuses, rewards linked to productivity, group performances or other indicators	0.241	**0.842**	0.242
Employees receive bonuses, rewards linked to productivity, company performances or other indicators	0.256	**0.828**	0.242
Qualified employees have the opportunity to be promoted to positions with higher salaries and higher responsibilities	0.441	**0.571**	0.336
Employee involvement			
Employees can express their concerns reasonably	**0.706**	0.209	0.342
Employees are involved in formal participatory processes (i.e. work group for quality enhancement, workgroups of problem solving, discussion panels, suggestion mechanisms)	**0.744**	0.267	0.309
Employees communicate among departments/offices/organizational units for problem solving and compliance with deadlines	**0.783**	0.162	0.303
Employees are informed by the company on organizational objectives	**0.822**	0.247	0.261
Employees are informed by the company on operative performances (e.g. productivity, quality, client satisfaction)	**0.804**	0.305	0.214
Employees are informed by the company on financial performances	**0.633**	0.477	0.18
Employees are informed by the company on market performances (e.g. market share, strategies)	**0.65**	0.441	0.199

RECR_TRAIN (dummy) takes value 1 if one or more of the practices related to education and training is adopted by the firm and zero otherwise. The percentage of firms in the sample adopting organisational practices that favour the implementation of improvements in recruitment and training of employees is 74%. Three dichotomised variables will be included, for robustness, in the empirical analysis.

3.3. Empirical strategy: the model

The main objective of the work is to analyse the way organisational settings of an enterprise influence the joint adoption of green and digital practices (*TWIN*): the empirical strategy tries to infer if those companies that have adopted twin practices (dependent variable) are also those that are implementing changes within their organisation (main explanatory variables: *EMPL_INVOLV*, *EVAL_PERF* and *RECR_TRAIN*) as it follows:

$$TWIN_{it} = \beta_1 EMPL\_INVOLV_{it} + \beta_2 EVAL\_PERF_{it} + \beta_3 RECR\_TRAIN_{it} + \beta_4 STEM_{it} + \beta_5 X_{it} + \alpha_i + \delta_t + u_i + \varepsilon_{it} \quad [1]$$

Recalling the unbalanced panel nature of the dataset and considering the nature of the dependent variable, the empirical analysis makes use of logit estimation with province, year and sector fixed effects:

- α regional NUTS2 or provincial NUTS3 fixed effect (in different estimations);
- δ time-wave fixed effect;
- u 2-digit Ateco sectorial fixed effect;
- ε is the error term.

STEM captures the skills and human capital, approximated by the relevance of skills in Science, Technology, Engineering and Math for the company. Firms were asked to rate the relevance of employees' skills for the company on a scale from 1 to 5. The variable takes value of 1 if the company assigns a value of 3 or more to

Table 4. Main descriptive statistics.

	Description	Mean	SD	Min	Max
DIGIT	Dummy: 1 if firm benefited from the Industry4.0 program	0.225	0.418	0	1
GREEN	Dummy: 1 if firm adopted any environmental innovation	0.396	0.489	0	1
TWIN	Dummy: 1 for DIGIT and GREEN firms	0.136	0.343	0	1
EMPL INVOLV(pca)	PC related to changes in involvement and participation of employees in critical decisions	−0.001	1.004	−3.705	3.44
EVAL PERF(pca)	PC related to changes in the mechanisms of performance evaluation of employees	0.001	0.981	−3.252	3.179
RECR TRAIN(pca)	PC related to changes in recruitment and training of employees	0	0.973	−3.745	4.13
EMPL INVOLV(dummy)	Dummy: 1 if at least one practice adopted	0.765	0.424	0	1
EVAL PERF(dummy)	Dummy: 1 if at least one practice adopted	0.535	0.499	0	1
RECR TRAIN(dummy)	Dummy: 1 if at least one practice adopted	0.744	0.436	0	1
EXPORT	Dummy:1 for exporting firms	0.463	0.499	0	1
RD INV	Dummy: 1 for firms undertaking R&D investments	0.297	0.457	0	1
AGE	Age of the firm	30.642	22.742	0	494
SMALL	Dummy: 1 for small firms (<50 empl.)	0.87	0.337	0	1
STEM	Dummy: 1 for firms with STEM competences (Programming, Scientific, Technical Engineering, Mathematics) declared to be relevant	0.41	0.492	0	1
MEDHIGHTECH	Dummy: 1 for high and medium high tech sectors	0.19	0.392	0	1
MEDLOWTECH	Dummy: 1 for medium low tech sectors	0.349	0.477	0	1
LOWTECH	Dummy: 1 for lowtech (benchmark dummy)	0.46	0.474	0	1

this set of skills. Possessing STEM skills can facilitate the emergence of digital practices in the company, so that we expect a positive sign for it.

Among the control variables (X) belong those variables that have been constructed by drawing on extant literature on the drivers of environmental innovations adoption.

RD_INV takes value 1 if the company has undertaken R&D investments. This variable account for the category of 'Technology Push' set of determinants that extant literature has identified as relevant determinants of environmental innovations adoption.

We then control for the size of the enterprise: SMALL takes value one for less than 50 employees and 0 for larger sizes. Additionally, we control for the AGE of the firm and for its exporting propensity: EXPORT takes value 1 for exporting firms.

Table 4 shows the summary of all the variable considered in the analysis. Correlation among relevant explanatory variables is presented in Table 5.

Being the focus on Italian manufacturing firms, we do not add any specific policy variable to capture the dimension 'Regulation'. Most of the core regulation towards green economy transition set at a higher institutional level than the one under scrutiny so there won't be enough variety in Italian provinces. However, to be sure to rule out possible regional heterogeneities in policy stringency, we account for the location of the firms by means of the geographical area dummies either conceived at regional NUTS2 level

Table 5. Pairwise correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) TWIN	1.000										
(2) EMPL_INVOLV	0.078***	1.000									
	(0.000)										
(3) EVAL_PERF	0.130***	−0.030***	1.000								
	(0.000)	(0.004)									
(4) RECR_TRAIN	0.112***	−0.011	−0.076***	1.000							
	(0.000)	(0.273)	(0.000)								
(5) EXPORT	0.137***	0.069***	0.080***	0.079***	1.000						
	(0.000)	(0.000)	(0.000)	(0.000)							
(6) RD_INV	0.267***	0.130***	0.143***	0.139***	0.318***	1.000					
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)						
(7) AGE	0.092***	0.025**	0.030***	0.015	0.182***	0.073***	1.000				
	(0.000)	(0.018)	(0.004)	(0.146)	(0.000)	(0.000)					
(8) SMALL	−0.137***	−0.016	−0.140***	−0.084***	−0.220***	−0.235***	−0.122***	1.000			
	(0.000)	(0.131)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)				
(9) STEM	0.180***	0.194***	0.150***	0.208***	0.186***	0.268***	0.053***	−0.154***	1.000		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)			
(10) MEDHIGHTECH	0.014	0.029***	0.089***	0.087***	0.197***	0.191***	0.012	−0.112***	0.178***	1.000	
	(0.168)	(0.006)	(0.000)	(0.000)	(0.000)	(0.000)	(0.270)	(0.000)	(0.000)		
(11) MEDLOWTECH	0.044***	−0.002	0.054***	0.048***	−0.083***	−0.083***	−0.039***	0.023**	0.051***	−0.355***	1.000
	(0.000)	(0.854)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.026)	(0.000)	(0.000)	

*p<0.10, **p<0.05, ***p<0.01.

Table 6. Main results logistic regression.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
EMPL_INVOLV(pca)	0.0591***			0.0939***	0.0951***		
	(0.0182)			(0.0206)	(0.0208)		
EVAL_PERF(pca)		0.1371***		0.1657***	0.1634***		
		(0.0188)		(0.0191)	(0.0193)		
RECR_TRAIN(pca)			0.0998***	0.1403***	0.1413***		
			(0.0193)	(0.0203)	(0.0205)		
EMPL_INVOLV(dummy)						0.0979*	0.0990*
						(0.0557)	(0.0564)
EVAL_PERF(dummy)						0.1680***	0.1738***
						(0.0429)	(0.0434)
RECR_TRAIN(dummy)						0.1651***	0.1660***
						(0.0555)	(0.0560)
EXPORT	0.1180***	0.1202***	0.1164***	0.1127***	0.1307***	0.1183***	0.1377***
	(0.0409)	(0.0411)	(0.0409)	(0.0413)	(0.0416)	(0.0411)	(0.0414)
RD_INV	0.7048***	0.6953***	0.7008***	0.6583***	0.6663***	0.6884***	0.6958***
	(0.0398)	(0.0400)	(0.0399)	(0.0402)	(0.0406)	(0.0400)	(0.0403)
AGE	0.0037***	0.0036***	0.0037***	0.0038***	0.0038***	0.0037***	0.0038***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0008)
SMALL	−0.2165***	−0.1735***	−0.2012***	−0.1633***	−0.1677***	−0.2014***	−0.2041***
	(0.0489)	(0.0494)	(0.0489)	(0.0497)	(0.0502)	(0.0492)	(0.0497)
STEM	0.3723***	0.3686***	0.3603***	0.2930***	0.2931***	0.3156***	0.3151***
	(0.0388)	(0.0386)	(0.0385)	(0.0399)	(0.0401)	(0.0393)	(0.0395)
CONSTANT	−4.4602***	−4.6203***	−4.6039***	−4.7894***	−4.6708***	−5.0132***	−5.1037***
	(0.1951)	(0.2264)	(0.1805)	(0.2200)	(0.2475)	(0.2163)	(0.2491)
N	8959	8959	8959	8959	8959	8959	8959
YEAR FE	Y	Y	Y	Y	Y	Y	Y
SECTOR FE (2-DIGIT)	Y	Y	Y	Y	Y	Y	Y
REGION FE	Y	Y	Y	Y		Y	
PROVINCE FE					Y		Y
pseudo R^2	0.1409	0.1471	0.1433	0.1558	0.1704	0.1475	0.1627

Standard errors in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01.

or, for robustness, at provincial NUTS3 level, and for the potential presence of sector-specific policies by means of the 2-digit sectoral variables.

We acknowledge that omitted factors, such as managerial capacity, which influence both the adoption of twin practices and organisational innovation, can introduce endogeneity bias in the analysis. To mitigate this potential issue, we attempt to implement a fixed effects model with the firm as the panel identifier. However, as it is often the case, such a demanding model, with more than 2000 individual dummies, nullifies the main effects found in the primary analysis in Table 6, as the individual fixed effects capture all

Table 7. Average marginal effect (variables at their means) of results in Table 6.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
EMPL_INVOLV(pca)	0.0111***			0.0174***	0.0174***		
	[0.00, 0.02]			[0.01, 0.02]	[0.01, 0.02]		
EVAL_PERF(pca)		0.0257***		0.0307***	0.0298***		
		[0.02, 0.03]		[0.02, 0.04]	[0.02, 0.04]		
RECR_TRAIN(pca)			0.0188***	0.0260***	0.0258***		
			[0.01, 0.03]	[0.02, 0.03]	[0.02, 0.03]		
EMPL_INVOLV(dummy)						0.0183*	0.0182*
						[−0.00, 0.04]	[−0.00, 0.04]
EVAL_PERF(dummy)						0.0315***	0.0320***
						[0.02, 0.05]	[0.02, 0.05]
RECR_TRAIN(dummy)						0.0309***	0.0306***
						[0.01, 0.05]	[0.01, 0.05]
EXPORT	0.0223**	0.0225**	0.0219**	0.0209**	0.0238**	0.0222**	0.0253***
	[0.01, 0.04]	[0.01, 0.04]	[0.01, 0.04]	[0.01, 0.04]	[0.01, 0.04]	[0.01, 0.04]	[0.01, 0.04]
RD_INV	0.133***	0.130***	0.132***	0.122***	0.122***	0.129***	0.128***
	[0.12, 0.15]	[0.12, 0.14]	[0.12, 0.15]	[0.11, 0.14]	[0.11, 0.14]	[0.11, 0.14]	[0.11, 0.14]
AGE	0.000696***	0.000678***	0.000697***	0.000696***	0.000700***	0.000692***	0.000694***
	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.00]
SMALL	−0.0408***	−0.0325***	−0.0378***	−0.0303***	−0.0306***	−0.0377***	−0.0376***
	[−0.06, -0.02]	[−0.05, -0.01]	[−0.06, -0.02]	[−0.05, -0.01]	[−0.05, -0.01]	[−0.06, -0.02]	[−0.06, -0.02]
STEM	0.0702***	0.0690***	0.0678***	0.0543***	0.0535***	0.0591***	0.0580***
	[0.06, 0.08]	[0.05, 0.08]	[0.05, 0.08]	[0.04, 0.07]	[0.04, 0.07]	[0.04, 0.07]	[0.04, 0.07]
N	8959	8959	8959	8959	8959	8959	8959

95% confidence intervals in brackets. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

the variability. For this reason, it is worth noting that our results should be considered as evidence of correlation and do not imply causation.

4. Results and discussion

Results of the empirical analysis are reported in Table 6, and the computed marginal effects with variables at their means in Table 7.

Column 1 to 3 report results for Equation 1 including separately the three variables of interest. Column 4 includes jointly the three organisational practices' variables along with year, 2-digit sectoral fixed effects in all columns and regional NUTS 2 fixed effects. Column 5 substitutes NUTS2 regional fixed effects with provincial NUTS3 fixed effects. Columns 6 and 7 include dichotomised variables for organisational practices (instead of PCA extracted ones), including year and sector fixed effects and NUTS2 or NUTS3 geographical fixed effects respectively. Results across the 7 Columns are consistent: signs and significance of all the estimations hold across the specifications.

The concept of twin transition considers the digitisation of the firm within a framework of sustainability and resource efficiency. Results robustly show that the way firms do organise internally matters in explaining their attitude towards achievements of both digitisation and environmental goals.

The three organisational practices are all significantly and positively correlated to the dependent variable, throughout the different specifications. Involving employees directly into firms' participatory processes and keeping them informed on the economic performance and the objectives of the firm (*EMPL_INVOLV*) help the firm reaching its objective of adopting innovations pertaining to both the paradigms. In line with the literature that recognise in employees' participation to decision-making a way to increase the capacity of the organisation to produce new and better ideas (Thompson 2003), the higher the employee's involvement into firm's strategic choices, the higher its probability to be successful in translating its strategy into an innovative outcome. Furthermore, investing into firm's employees training or hiring qualified employees (*RECR_TRAIN*) also positively contributes to achieving firms' innovative objectives: the better and more qualified a firm's human capital, the higher its probability in being a successful innovator. In this case, we meaningfully enter the dimension of capabilities related to the organisational learning and the firm absorptive capacity, with the strong positive implications they have for the innovative activity of the firm. Innovations are likely to be adopted where the knowledge base of

the firm is ready to exploit them, possibly providing competitive advantages in line with the Porter hypothesis for green technologies. At the same time, employees need to be given the right level of incentives to experience this virtuous circle: firms undertaking mechanisms to reward more productive attitudes in their employees (*EVAL_PERF*) face better innovative outcomes. *EVAL_PERF* is also the set of organisational practices with the highest coefficient despite improvements in performance evaluations are less adopted among the firms in the sample. This result is consistent both when the three organisational variables are extracted from the principal component analysis (Column 1–5) and when are dichotomises (Column 6–7). Although no causality can be claimed from this study, results stemming from the dichotomised variables allow discussing the magnitude of the effects at stake. Implementing *EVAL_PERF* practices is associated to a probability of 3.2% to observe TWIN practices in that firm, falling to 3.1% for *RECR_TRAIN* and 1.8% for *EMPL_INVOLV* (Column 7 Table 7). Whereas the magnitude in the coefficients associated to EVAL_PERF and RECR_TRAIN is similar, the organisational practice that seems to be less important for the emergence of TWIN practices is EMPL_INVOLV, being its coefficients systematically lower than the others.

Pertaining the remaining control variables, there is a negative and significant sign for small enterprises signalling that the joint adoption of both digital and green innovations is much more likely to occur for medium/large firms. This is also consistent to recent studies evidence for Italy, in which the probability of firms to invest in digital technologies (Cirillo et al. 2023a, 2023b) and in adopting eco-innovations (Leoncini et al. 2019) was increasing with the size of the firm. Age is another factor which is significant in explaining the probability of adopting both green and digital practices: older firms present higher probabilities of undertaking 'twin' practices. Furthermore, older firms are better able to exploit mature knowledge because they already have experience in their sector to integrate the new technologies in their processes in the most effective way (Messeni Petruzzelli et al. 2018) and are less financially constrained than SMEs for greening their production processes and products (Ghisetti et al. 2017).

R&D investing firms develop the technological competences needed to be effective innovators in both digital and green practices, consistently with existing literature.

Exporting firms are more likely to adopt both types of innovations than non-exporting ones, as they are more exposed to market pressures and to changing regulatory pressures forcing them to be greener than their domestic counterparts. Lastly, *STEM* competencies and skills matter for the 'twin' transition: those enterprises considering STEM skills relevant for their employees are more likely to succeed in 'twin' practices as the two paradigms involve technological improvements of business operations. Thus, they require human capital with appropriate skills to deal with those changes.

To shed light on where organisational set-ups matter the most, we lastly performed a seemingly unrelated bivariate probit (Greene 2018) on the two mutually correlated variables that allowed constructing TWIN, respectively, GREEN and DIGIT. Results, reported in Table 8, show that both GREEN and DIGIT benefit from all the three organisational practices. This implies that our main finding is driven, as expected, by the relevance of organisational practices for driving both the green and the digital transformation for our sample of firms.

Additionally, we observe greater coefficients associated to organisational practices when the dependent variable is GREEN, leading us to conclude that most of the effect of organisational practices is linked to their relevance in treating the complexity of the green transition, which is highly dependent upon complementary technological and organisational skills. The small size of the firm which at the aggregate analysis presented in Tables 6 and 7 was significant and negative, is confirmed to hamper the digitalisation process (column 2 and 4 of Table 8), whereas is not robustly affecting the green transformation. Being smaller, in other words, affects the twin transition mostly by its detrimental effect on digitalisation capabilities rather than by the green ones. As for the remaining variables and controls, coefficients in the two bivariate probits are comparable, leading us to conclude that the main difference between DIGIT and GREEN is actually in the effects exerted by the three organisational practices variables. The way in which firms do organise internally, seems to matter for both the green and the digital transformation, but the green transformation complexity is more affected by organisational HRM practices than the digital one.

Table 8. Seemingly unrelated bivariate probit on GREEN and DIGIT.

	Model 1		Model 2	
	Eq(1)	Eq(2)	Eq(1)	Eq(2)
	GREEN	DIGIT	GREEN	DIGIT
EMPL_INVOLV(pca)	0.1681***	0.0477***	0.1665***	0.0459***
	(0.0152)	(0.0169)	(0.0153)	(0.0171)
EVAL_PERF(pca)	0.1935***	0.1166***	0.1934***	0.1157***
	(0.0151)	(0.0165)	(0.0153)	(0.0167)
RECR_TRAIN(pca)	0.1884***	0.0852***	0.1911***	0.0843***
	(0.0156)	(0.0171)	(0.0158)	(0.0173)
EXPORT	0.1224***	0.1821***	0.1240***	0.1846***
	(0.0323)	(0.0355)	(0.0326)	(0.0360)
RD_INV	0.6219***	0.5607***	0.6259***	0.5706***
	(0.0338)	(0.0355)	(0.0341)	(0.0360)
AGE	0.0037***	0.0019***	0.0039***	0.0020***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)
SMALL	−0.0648	−0.1993***	−0.0609	−0.2058***
	(0.0448)	(0.0456)	(0.0452)	(0.0462)
STEM	0.2231***	0.2589***	0.2241***	0.2618***
	(0.0319)	(0.0345)	(0.0322)	(0.0349)
CONSTANT	−0.4215***	−1.1599***	−0.4592***	−1.2675***
	(0.1056)	(0.1187)	(0.0917)	(0.1060)
RHO	0.2630***	0.2601***	0.2713***	0.2679***
	(0.0210)	(0.0211)	(0.0208)	(0.0210)
N	8959		8959	
YEAR FE	Y		Y	
SECTOR FE (2-DIGIT)	Y		Y	
REGION FE	Y			
PROVINCE FE			Y	
AIC	18887		18967	
BIC	19632		20692	

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5. Conclusions

The 'twin' transition is an imperative to create the conditions for a sustainable development and growth. It is driven by increasing policy attention, but at the same time it is far from being a simple goal to be reached due to the necessity to integrate different investment domains within a firm. This is especially true in countries that lag behind in overall R&D and may find compensations in the complementarity between innovation domains, including human resource management.

At the firm level, such transition requires firms to transform their business models to embrace several new circular and environmental practices such as changing their raw resources in favour of regenerative, recyclable or reusable ones; making waste a resource; design longer lasting products; facilitating services such as pay per use they may have not been familiar with. To be able to adopt those practices, firms are thus actually required to change substantially their business models (Linder and Williander 2015). This paper addresses the fact that the joint adoption of green and digital practices is not only a matter of technological competences and capabilities but it requires other softer competences, namely those revolving around the organisational domain.

In line with the set of works that recognises organisational capabilities as strictly interconnected to the innovative capacity of the firm (Capriati and Divella 2020) the paper explored the relations between different dimensions of the internal-to-the-firm organisation of labour, which imply different dimension of the organisational capabilities, and the adoption of 'twin' practices.

Moving from these premises, a new piece of evidence is conveyed on how firms can heterogeneously respond to the challenges above and be successful innovators. By recognising the complexity of such challenge, the current work tries to shed light on the determinants of 'twin' practices, a topic that has not yet been sufficiently investigated using firm level lenses. In trying to analyse the determinants, at the firm level, of 'twin' practices we include a quite neglected dimension: the role of organisational set-ups, especially HRM.

The analysis, conducted on a representative sample of Italian manufacturing firms, confirms a pivotal role for different practices firms may or may not embrace, confirming the expectations that organisational set ups have a key role. The paper suggests that i) the higher is employees' involvement into firms' activities and

strategic objectives, ii) the better qualified is firm's human capital and iii) the higher is the presence of rewarding schemes for employees good performance, then the higher is the probability for such firm to be successful in 'twinning' its green and digital practices with respect to its peers. The complexity of the 'twin' transition not only requires technological capabilities and STEM competences but also specific organisational set-ups that allow making such transition effective. In this context, the role of HRM is not only related to recruitment and reskilling but also to foster the involvement of employees in the strategic decisions of the firm along with providing more suitable practices of performance evaluation. Firms' managers must be aware of the importance of the organisational practices adopted as a potential ground for the adoption and implementation of 'twin' practices for responding to the current policy challenges. Managers of human resources should be more aware of the potential of this business area in fostering a 'twin' transition (Kramar 2014). Considering also the magnitude of the results, giving employees the right rewards and incentives (*EVAL_PERF*) seems to be crucial in making the 'twin' transition more effective.

While the results are informative, more research in the area should be undertaken. First, due to the absence of relevant variables to be used in a Heckman-type selection model, we did not model explicitly the firm choice of adopting digital practices financed by the program Industry 4.0 (*DIGIT*). Second, it be extended over time to better grasp the intertwined dynamic among the firm strategies analysed in the paper. Finally, focusing attention on specific regions and/or sectors, through in-depth surveys, could be relevant in pointing out regional and sector heterogeneity.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

Claudia Ghisetti acknowledges financial support under the National Recovery and Resilience Plan (NRRP), Mission 4, Component 2, Investment 1.1, Call for tender No. 104 published on 2.2.2022 by the Italian Ministry of University and Research (MUR), funded by the European Union – NextGenerationEU– Project Title - Digital and green transitions in Italian businesses: An assessment of the main antecedents – Grant Number 2022CS5X8Y, - Grant Assignment Decree No. n. 967 del 30/06/2023 by the Italian Ministry of Ministry of University and Research (MUR). Massimiliano Mazzanti and Francesco Nicolli acknowledge financial support from PNRR MUR project ECS_00000033_ECOSISTER, funded under the National Recovery and Resilience Plan (NRRP), Mission 04 Component 2 Investment 1.5 – NextGenerationEU, Call for tender n. 3277 dated 30/12/2021 Award Number: 0001052 dated 23/06/2022.

ORCID

Davide Antonioli http://orcid.org/0000-0001-5150-3714
Claudia Ghisetti http://orcid.org/0000-0002-8930-2579
Massimiliano Mazzanti http://orcid.org/0000-0002-6538-7942
Francesco Nicolli http://orcid.org/0000-0001-8109-5969
Marco Quatrosi http://orcid.org/0000-0002-9409-9608

Compliance with ethical standards

The authors do not have any conflict of interest to disclose. No human/animal participants involved in this study

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Appendix

Appendix A1

Table A1– Organisational practices used in the Principal component analysis.

Question	Answer	Frequency	Question	Answer	Frequency
Candidates upon hiring undergo structured interviews (questions related to the job, standardised for every candidate with objective measurement scale)	Never	18,21%	Employees receive bonuses, rewards linked to productivity, company performances or other indicators	Never	29,41%
	Seldom	9,85%		Seldom	13,98%
	Sometimes	17,82%		Sometimes	22,24%
	Often	21,88%		Often	11,12%
	Very often	13,38%		Very often	7,75%
	Don't know	18,85%		Don't know	15,50%
Candidates upon hiring undergo formal tests (written test or simulations of problem solving of real cases)	Never	54,91%	Qualified employees have the opportunity to be promoted to positions with higher salaries and higher responsibilities	Never	1,97%
	Seldom	12,17%		Seldom	4,13%
	Sometimes	10,30%		Sometimes	18,39%
	Often	4,11%		Often	36,91%
	Very often	2,29%		Very often	27,49%
	Don't know	16,23%		Don't know	11,12%
Employees receive professional training	Never	4,24%	Employees can express their concerns reasonably	Never	2,25%
	Seldom	4,38%		Seldom	4,93%
	Sometimes	21,94%		Sometimes	18,39%
	Often	31,53%		Often	35,96%
	Very often	27,96%		Very often	30,09%
	Don't know	9,96%		Don't know	8,37%
Results of performance evaluation are used to determine training needs of employees	Never	18,06%	Employees are involved in formal paricitpatory processes (i.e. work group for quality enhancement, workgrous of problem solving, discussion panels, suggestion mechanisms)	Never	12,64%
	Seldom	11,73%		Seldom	14,70%
	Sometimes	25,02%		Sometimes	25,55%
	Often	17,73%		Often	21,64%
	Very often	8,08%		Very often	11,79%
	Don't know	19,37%		Don't know	13,66%
Employees are refunded for external training courses	Never	17,51%	Employees communicate among departments/offices/organisational units for problem solving and compliance with deadlines	Never	4,72%
	Seldom	5,01%		Seldom	5,86%
	Sometimes	9,82%		Sometimes	20,38%
	Often	15,00%		Often	34,19%
	Very often	30,65%		Very often	23,92%
	Don't know	22,02%		Don't know	10,91%
Employees receive formal evaluation of their performances	Never	33,70%	Employees are informed by the company on organisational objectives	Never	7,59%
	Seldom	13,54%		Seldom	10,39%
	Sometimes	17,39%		Sometimes	25,42%
	Often	11,44%		Often	27,96%
	Very often	6,59%		Very often	16,77%
	Don't know	17,34%		Don't know	11,86%
Raises of salaries are based on employees' performances	Never	13,30%	Employees are informed by the company on operative performances (e.g. productivity, quality, client satisfaction)	Never	10,53%
	Seldom	8,92%		Seldom	12,50%
	Sometimes	23,97%		Sometimes	28,32%
	Often	23,37%		Often	24,67%
	Very often	15,16%		Very often	12,07%
	Don't know	15,28%		Don't know	11,90%
Employees receive bonuses, rewards linked to productivity, individual performances or other indicators	Never	20,98%	Employees are informed by the company on financial performances	Never	39,66%
	Seldom	13,09%		Seldom	21,79%
	Sometimes	27,58%		Sometimes	15,86%
	Often	14,75%		Often	6,35%
	Very often	9,45%		Very often	2,68%
	Don't know	14,15%		Don't know	13,66%
Employees receive bonuses, rewards linked to productivity, group performances or other indicators	Never	34,81%	Employees are informed by the company on market performances (e.g. market share, strategies)	Never	33,59%
	Seldom	14,31%		Seldom	19,94%
	Sometimes	19,60%		Sometimes	19,35%
	Often	9,26%		Often	9,58%
	Very often	6,04%		Very often	3,45%
	Don't know	15,98%		Don't know	14,09%

Appendix A2

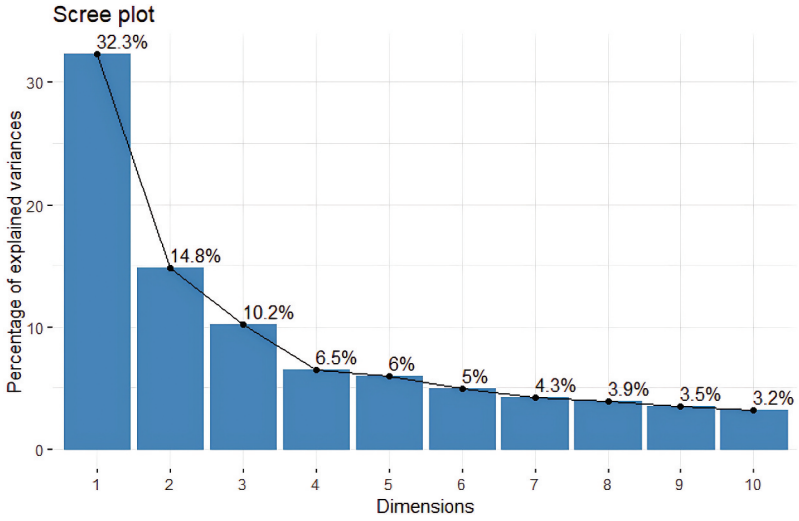

Figure A1. Scree plot of the Principal component analysis.

Principal Component Analysis has been used to reduce the dimensionality of the data without endangering interpretability. After running PCA to the data, the result is a set of components uncorrelated among each other that are a linear combination of the original variables. This helps reducing the risk of multicollinearity in the estimation (Daoud 2017). Table 3 shows the loadings of the Principal Components computed out of the 18 hRM variables. Polychoric correlation is used to deal with categorical variables where it is assumed data follow an underlying normal distribution (Ekström 2011). On the other hand, the optimal number of components for the PCA has been chosen plotting the eigenvalues coming from the matrix of observed data with those coming from a random (polychoric) matrix of the same size as the original (e.g. parallel analysis). The optimal number of components, as suggested by the sample, would provide a sharp break in the plot. Once identified the suggested number of components (in this case 3), PCA has been run using the varimax method for the rotation of the matrix of components whereas scores have been computed using the regression method (DiStefano, Zhu, and Mîndrilã 2009). The varimax method provided components with variable near to zero and far from zero. This helped in yielding more interpretable components. The three-component solution represents the optimal solution according to the parallel analysis and it explains 57.3% of the variance of the original variables (Figure A1). All the 18 variables appear to positively contribute to the components as no negative sign is present in the loadings. The variables that form a component are those with a loading higher than 0.5. According to the parallel analysis run:

EMPL_INVOLV: these components collect all the questions asking the level of communication to employees with regards to strategic decision of the firm. Questions that form this component are coloured in yellow in Table 3. Respondents were asked whether employees could share their concerns reasonably or if they are actively involved in providing suggestions through workgroups. There is another set of questions that ask respondents whether organisational objectives or market, financial performances were communicated to employees.

EVAL_PERF: the second component collects questions related to employee evaluation performance mechanisms. Questions that form this component are coloured in green in Table 3. This set of questions asked whether employees are rewarded based on either their individual or group performances or if their salary is based on performance. There is also a question related to whether qualified employees are promoted.

RECR_TRAIN: the third component collects questions related to the recruitment and training process within the enterprises. Questions that are part of this component are coloured in orange in Table 3. The questions related to recruitment ask whether candidates undergo structured interviews or formal tests. The set of questions related to training asks whether employees undergo professional training, whether they are refunded for the training and if training needs are determined from employees' performances.