ERC
Enterprise Research Centre

Twin Green and Digital Transitions:
Joint adoption of net zero and digital practices by UK SMEs

ERC Insight Paper

October 2021

www.enterpriseresearch.ac.uk

Twin Green and Digital Transitions: Joint adoption of net zero and digital practices by UK SMEs

Dr Effie Kesidou
Enterprise Research Centre and Leeds University Business School,
e.kesidou@leeds.ac.uk

Dr Anastasia Ri
Enterprise Research Centre and Aston Business School
a.ri@aston.ac.uk

The Enterprise Research Centre is an independent research centre which focusses on SME growth and productivity. ERC is a partnership between Warwick Business School, Aston Business School, Queen's University School of Management, Leeds University Business School and University College Cork. The Centre is funded by the Economic and Social Research Council (ESRC); Department for Business, Energy & Industrial Strategy (BEIS); Innovate UK, the British Business Bank and the Intellectual Property Office. The support of the funders is acknowledged. The views expressed in this report are those of the authors and do not necessarily represent those of the funders.

EXECUTIVE SUMMARY / KEY FINDINGS

In this insight paper we assess the so-called "twin" green and digital transition premise. This refers to the potential of digital technologies to facilitate the transition to a sustainable economy. Here, our central focus is whether UK SMEs jointly adopt net zero and digital practices. We draw information from ERC Business Futures Survey of over 1,000 SMEs that was conducted between September and November 2020, as it allows us to identify complementarities-in-use between different types of net zero and digital technologies.

Despite all the hype about "twin" green and digital transition, there is remarkably little evidence on whether digital technologies are actually enabling green growth at either macro, meso, or micro level. In this paper, we find evidence of only a handful of complementarities between net zero and digital technologies. **First**, synergies exist between use of *CRM* and undertaking of *environmental reports and audits*, *switching to renewable energy,* and introducing *low carbon products and services*. This suggests an increased pay-off for firms that jointly adopt customer-focused digital systems and practices aiming to reduce, measure and showcase environmental impact, especially in addressing customers' needs and improving firm's reputation. Firms looking to enhance customer's experience by making their products or services more environmentally friendly would benefit from digitalising their back-office processes.

Second, we find some evidence suggesting synergies between digitalisation (use of e-commerce, accountancy and HR software, video-conference and collaboration tools) and *changes in production/ processes to reduce carbon emissions*. **Finally**, our results point out to synergies between advanced digital technologies such as *AR/VR* and *AI/ML* and *investment in R&D related to the environment*. Although the intensity of the synergetic effects is relatively low, this result is still very important because it showcases potential benefits and future development of digitally enabled eco-innovation in UK SMEs. The results also point out on synergies between *AR/VR* and organisational net zero practices, such as *training on environmental matters* and low carbon *market research*.

Keywords: SMEs, net zero, environment, digital, digital transformation, twin transition, complementarities.

CONTENTS

1. Introduction

Climate emergency requires urgent and radical reduction in carbon footprint[1]. The UK's Net Zero Emissions Law aims to reduce CO2 to zero by 2050 and has set a vision of a green economic recovery from the Covid-19 crisis (BEIS, 2020). The "twin" green and digital transition could potentially transform the economy towards a low-carbon green path. For instance, a recent report by The Royal Academy[2] outlines ways whereby, at systemic level, digital infrastructure technologies could develop data applications in pursuit of net zero, such as systems of emission monitoring, satellite data management and analysis, and data about energy use in buildings, among other things. In the same vein, the EU's post-Covid-19 strategic vision is based on "a collective and cohesive recovery that accelerates the twin green and digital transitions…" (European Commission[3], 2020, p.2). Yet, despite the potential of digital technologies enabling a net zero transition, empirical micro-evidence of their connection is scarce.

In this paper, we explore the relationship between eight [technological and organizational] net zero practices and ten digital technologies, so as to better understand the complementarities between different types of net zero and digital practices. The complementarities perspective is useful because it sheds light on how relationships between elements of a system generate greater value than the system's individual parts (Milgrom and Roberts, 1990, 1995). Here, we follow the complementarities-in-use or adoption approach (Ballot et al., 2015; Battisti & Stoneman, 2010), whereby we examine the conditional (on other factors) probability of adoption of net zero and digital practices.

Our analysis is based on data from ERC Business Futures Survey of over 1,000 SMEs that was conducted between September and November 2020. Section 2 provides the descriptive statistics of the net zero and digital practices, that allows us to understand their diffusion across SMEs in UK. Next, in section 3, we explore the relationships between net zero and digital practices based on non-parametric correlation. However, correlation

[1] Carbon footprint refers to the total amount of GHG produced directly and indirectly by human activities. It is calculated in tons, as the sum of all emissions of carbon dioxide (CO2).
[2] The Royal Society (2020) *Digital technology and the planet: Harnessing computing to achieve net zero* Issued: December 2020 DES7035.
[3] https://ec.europa.eu/info/sites/default/files/communication-europe-moment-repair-prepare-next-generation.pdf

between two practices does not necessarily imply complementarity. Section 4 presents the complementarity-in-use or adoption approach we employ, whereby we examine the conditional (on firm, industry, and geographic factors) probability of adoption of net zero and digital practices. Section 5 discusses the results of the analysis, and section 6 concludes.

2. Net zero and digital practices of UK SMEs

The ERC Business Futures Survey of over 1,000 SMEs was conducted between September and November 2020. The dataset contains information on a wide range of practices and technologies that UK SMEs undertake and use in their business operations. Therefore, it represents a valuable source for our purpose: to better understand what types of practices are used simultaneously and to explore possible synergetic effect between net zero practices and digital technologies.

In particular, the dataset contains information on whether firms introduced technological and organisational innovations to minimise their environmental impact. Regarding technological net zero practices, firms were asked if they made any *changes in production and/or distribution processes* (*NZ2*), engaged in *environmental R&D* (*NZ3*), introduced *new low carbon products and services to the market* (*NZ7*), switched to more *renewable energy* (*NZ8*) or improved *pollution filtering (NZ3*). Further to these technological practices, firms were also asked whether they have made organisational changes such as *undertaking environmental reports or audits* (*NZ1*), conducted *training on environmental matters* (*NZ5*) or conducted *market research related to low carbon products or services* (*NZ6*).

The dataset also covers a wide range of digital technologies: from well-established technologies which became relatively common such as *accounting and HR software* (D3), *E-commerce* (D1), *online marketing and social media* (D2), *video conferencing* (D5); through more sector specific and/or less well diffused among smaller firms technologies, such as *computer aided design* software (D7) and *CRM systems* (D4); to recently emerged Industry 4.0 technologies, such as *cloud-computing solutions* (D6), *Internet of Things* (D8), *Augmented and Virtual Reality* (D9) and *Artificial intelligence and machine learning* (D9).

Table 1 reporting descriptive statistics provides information on what proportion of firms in the sample adopted net zero and digital practices. Almost 2 in 5 firms introduced changes in production or distribution processes (38.5%). More than 1 in 4 SMEs in the sample

engaged with environmental training (26.1%), introduced new low carbon products or services (25.1%) or switched to more renewable energy (29.7%).

Regarding digital practices, about 3 in 4 firms in the sample adopted E-commerce (73.3%), online marketing (76.2%), accounting / HR software (79.5%) and IoT (72.1%). Cloud-computing solutions were adopted by 3 in 5 firms (60.4%), and about 1 in 9 firm in the sample also reported use of AR/VR (10.8%) or AI and ML (11.6%).

Table 1. Descriptive statistics

Variables		Mean	Std. Dev.
Net zero practices			
NZ1	Environmental reports (1/0)	0.219	0.414
NZ2	Changes in production or distribution processes (1/0)	0.385	0.487
NZ3	Environmental R&D (1/0)	0.144	0.351
NZ4	Air pollution monitoring and filtering (1/0)	0.193	0.395
NZ5	Environmental training (1/0)	0.261	0.440
NZ6	Low carbon market research (1/0)	0.158	0.365
NZ7	New low carbon products or services (1/0)	0.251	0.434
NZ8	Switched to more renewable energy (1/0)	0.297	0.457
Digital technologies			
D1	Website to sell goods or services (1/0)	0.733	0.442
D2	Online marketing and social media (1/0)	0.762	0.426
D3	Accounting or HR software (1/0)	0.795	0.404
D4	Customer Relationship Management (CRM) system (1/0)	0.465	0.499
D5	Video conferencing such as teams or zoom (1/0)	0.637	0.481
D6	Cloud computing solutions (1/0)	0.604	0.489
D7	Computer Aided Design Software (CAD) (1/0)	0.368	0.483
D8	Internet of Things (IoT) (1/0)	0.721	0.449
D9	Augmented and Virtual reality (AR and VR) (1/0)	0.108	0.311
D10	Artificial Intelligence (AI) and Machine Learning (ML) (1/0)	0.116	0.320
Number of observations: 1,019			

Source: ERC Business Futures Survey
Observations are weighted to give representative results.

3. Exploring potential complementarities

To explore the extent to which SMEs undertook multiple net zero and digital practices simultaneously, we report in Table 2 Kendall's pairwise tau-b correlation coefficients. These represent the degree of association based on the number of concordances and discordances in each pair of practices. For all pairs of net zero practices, there is a statistically significant association (in bold green) meaning that adopting one net zero practice is not independent of adopting another net zero practice. This may indicate the complementarity-in-use of net zero practices with firms adopting a portfolio of environmental practices rather than adopting them separately (Ozusaglam et al., 2018).

There is a particularly high correlation between environmental trainings and environmental reports.

We also observe positive and significant correlations between use of different digital technologies (in bold blue). Thus, for example, the use of E-commerce is associated with online marketing, but also – to a lesser extent – with accounting and HR software, CRM, cloud and IoT. Use of AI / ML is strongly associated with the use AR/VR, CRM and cloud, but also with CAD and video conferencing tools.

Table 2. Correlation matrix – non-parametric Kendall's tau_b correlation coefficient

	NZ1	NZ2	NZ3	NZ4	NZ5	NZ6	NZ7	NZ8	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
NZ1	1.00																	
NZ2	**0.28**	1.00																
NZ3	**0.28**	**0.22**	1.00															
NZ4	**0.26**	**0.31**	**0.21**	1.00														
NZ5	**0.46**	**0.30**	**0.29**	**0.30**	1.00													
NZ6	**0.27**	**0.23**	**0.37**	**0.26**	**0.32**	1.00												
NZ7	**0.24**	**0.29**	**0.26**	**0.31**	**0.30**	**0.36**	1.00											
NZ8	**0.27**	**0.28**	**0.19**	**0.26**	**0.28**	**0.32**	**0.29**	1.00										
D1	0.07	**0.14**	0.08	0.07	**0.13**	**0.08**	**0.11**	0.03	1.00									
D2	0.05	**0.09**	0.04	0.05	**0.11**	**0.11**	**0.09**	0.07	**0.27**	1.00								
D3	0.06	**0.14**	0.04	0.04	**0.09**	0.04	**0.11**	0.01	**0.17**	**0.18**	1.00							
D4	**0.18**	**0.14**	**0.08**	0.07	**0.14**	**0.10**	**0.17**	**0.16**	**0.18**	**0.14**	**0.18**	1.00						
D5	**0.19**	**0.19**	0.08	0.03	**0.18**	0.06	**0.10**	**0.15**	0.08	**0.18**	**0.25**	**0.26**	1.00					
D6	**0.15**	**0.16**	**0.14**	**0.12**	**0.12**	**0.12**	**0.18**	**0.13**	**0.13**	**0.14**	**0.21**	**0.25**	**0.34**	1.00				
D7	**0.19**	**0.12**	**0.09**	**0.11**	**0.16**	**0.15**	**0.08**	**0.10**	**0.12**	**0.09**	**0.11**	**0.14**	**0.17**	**0.12**	1.00			
D8	**0.08**	**0.14**	**0.11**	**0.14**	**0.13**	**0.12**	**0.15**	**0.11**	**0.18**	**0.14**	**0.20**	**0.10**	0.07	**0.10**	**0.11**	1.00		
D9	**0.10**	0.01	**0.12**	**0.09**	**0.12**	**0.09**	**0.13**	0.05	0.04	0.07	0.02	**0.13**	**0.15**	**0.12**	**0.20**	0.08	1.00	
D10	**0.08**	0.08	**0.11**	**0.08**	**0.10**	**0.12**	**0.09**	0.05	0.05	0.06	0.04	**0.20**	**0.13**	**0.18**	**0.16**	0.05	**0.26**	1.00

Source: ERC Business Futures Survey
Note: Correlations significant at 0.01 level: in bold **green** - between different Net Zero practices, in **blue** – between different digital technologies, and in **orange** – between Net Zero and Digital practices.
NZ1- environmental reports or audits; NZ2 - Changed processes or transport/logistics to reduce carbon emissions; NZ3 - Invested in research and development related to the environment; NZ4 - Introduced air pollution monitoring and filtering; NZ5 - Conducted training on environmental matters; NZ6 - Conducted market research related to low carbon products or services; NZ7 - Introduced new low carbon products or services; NZ8 - Switched to more renewable energy; D1 - Website to sell goods or services; D2 - Online marketing and social media; D3 - Accounting or HR software; D4 - CRM system; D5 - Video conferencing; D6 - Cloud computing solutions; D7 - Computer Aided Design(CAD); D8 - Internet of things; D9 - Augmented and Virtual reality; D10 - AI and Machine learning

Numbers in bold orange indicate that there is also a potential complementarity crosswise between net zero and digital practices, although the intensity of these associations are, on average, less substantial than between net zero practices only or digital practices only.

Two of net zero practices, environmental training and introducing new low carbon products/services, are positively and significantly associated with all ten digital technologies, although the intensity of this association varies. For instance, for new low carbon products, the highest correlation coefficients are observed with cloud, CRM systems and IoT, while for environmental training – with video conferencing tools and CAD. Interestingly AI/ML has the highest correlation coefficients with environmental R&D and low carbon market research. This may indicate that some of UK SMEs are undertaking data-driven and digitally enabled environmental R&D and green innovations.

However, significant positive pairwise correlations, although suggesting possible synergies between net zero and digital practices, are not sufficient to prove the existence of such synergies. Indeed, other factors, such as firm or sector characteristics, may explain the correlation between practices.

To further explore possible complementarities between net zero and digital practices, we follow theoretical and econometric framework proposed by Battisti & Stoneman (2010) to analyse complementarities between a range of technological and organisational innovations using data from the UK Community Innovation Survey. The theoretical framework is grounded in economic analysis of technological diffusion and develops a model of adoption of innovation based on profitability considerations. This model does not assume that the optimal rate of adoption is 100%, on the contrary the optimal adoption level is driven by each firm's characteristics, profitability considerations and changing internal and external environment. In this framework, *complementary (exhibiting synergies) innovations* are defined as 'innovations where the overall gain from joint adoption is higher than the sum of the net gains from individual adoption' (Battisti & Stoneman, 2010, p.191). In other words, there is a synergy between two innovative practices when the adoption of one practice increases the marginal payoff of another. Regarding net zero and digital practices, we may expect, for example, that when environmental reports and audits are undertaken simultaneously with changes in production and / or distribution processes, the former may increase the effectiveness of the later. Considering that measurement of carbon emissions is the key step for SMEs to begin their net zero journey, digital tools may help businesses to better identify their largest emissions hotspots, make the adoption of net zero practices more cost efficient, and lead to a more effective decision-making regarding further steps to minimise environmental impact.

From econometric perspective, such complementarities are shown when in the modelling of the probability of adoption, after controlling for the effect of firm, industry, and geographic characteristics that may influence the correlation between a pair of practices, there is still a positive conditional covariance between these two practices. To operationalise this methodology, we first run a series of univariate probit regressions for each one of the net zero and digital practices to model the probability of adoption by UK SMEs conditional on a number of firm, industry, and geographic characteristics which may impact adoption behaviour (Section 4). Then, in the second step, we examine the significance and the sign of the relationship between residuals resulted from probit models to establish the existence of complementarity between practices (Section 5). The degree of association between residuals of the conditional probability of adoption models would be indicative of the intensity of complementarity / synergetic effect between practices.

4. Modelling conditional probability of adoption

Table 3 reports the coefficients resulting from the estimation of eight probit models for each net zero practice and Table 4 – of probit models for each of ten digital technologies. These models of probability of adoption of net zero and digital practices included the following variables relating to industry and firm characteristics:

- Firm *size* is a commonly used variable to diffusion of innovation studies as it has been shown to influence positively and significantly the probability of technology adoption with larger firms being more generally more likely to adopt that smaller ones. Firm size may also capture some firm characteristics, such as managerial abilities, efficiency and availability of resources that may affect adoption of new practices.
- Firm *age* is also an important variable to include in innovation adoption model. On one hand, it can be argued that older businesses have more experience to evaluate costs and benefits of introducing innovations. But on the other hand, they may be less flexible and open to change. The same argument may be applied to *multisite* organisations due to their more complex organisational structure.
- Firm *sector* reflects market conditions to which a firm is exposed and also captures sector-specific pre-dispositions and payoffs of adoption of innovations. *Nation* accounts for geographic specificities of the business environment.

- We also include rural dummy to account for the environment in which firm operates. Differences in infrastructure endowments and regulations may have effect on the probability of adoption.
- We include *business plan* as a measure of managerial capability which was shown to be associated with adoption of sustainability practices. Internationalisation may also increase incentives to adoption of new practices if a firm is exposed to high competitive or value chain pressure, therefore we include a dummy variable to indicate whether a firm is *exporting* or not.

Moreover, to account for environmental characteristics specific to net zero and digital practices, we include into the respective models the following:

- Based on previous literature (Kesidou and Demirel, 2012; Kesidou and Wu, 2020; Kesidou and Ri, 2021) we include a set of *drivers of net zero practices*. *External* factors such as government policies, voluntary regulations, external finance, and customer demand and *internal* business-level factors including the motivation of businesses to improve their image and reputation and to reduce costs may influence the uptake of net zero practices.
- Firms may also be exposed to a range of specific barriers retaining them from adoption of digital technologies. These relate to *internal factors* – such as resource constraints regarding *digital skills*, *lack of funds* to purchase technology, or else organisational complexities accompanying introduction of new technologies (*compatibility with existing equipment*, *internal resistance to change* in the workforce) – and external factors, such as *broadband capacity* and *cyber risk*. For instance, broadband capacity may limit the deployment of data-driven systems which necessitate high broadband speed (Ri and Luong, 2021).

Table 3. Control factors and the probability of adoption of NetZero practices, probit coefficients

	(1) NZ1	(2) NZ2	(3) NZ3	(4) NZ4	(5) NZ5	(6) NZ6	(7) NZ7	(8) NZ8
Driver1	0.189***	0.030	0.191***	0.140**	0.102*	0.025	0.034	-0.016
	(0.060)	(0.060)	(0.067)	(0.061)	(0.056)	(0.067)	(0.060)	(0.054)
Driver2	-0.047	0.061	-0.013	-0.073	-0.102*	0.024	-0.057	-0.014
	(0.060)	(0.054)	(0.056)	(0.059)	(0.057)	(0.062)	(0.053)	(0.054)
Driver3	0.148***	0.209***	0.203***	0.062	0.157***	0.285***	0.191***	0.195***
	(0.057)	(0.053)	(0.057)	(0.058)	(0.055)	(0.058)	(0.054)	(0.052)
Driver4	-0.051	0.022	-0.069	0.086	0.089	0.017	0.018	-0.014
	(0.060)	(0.057)	(0.061)	(0.062)	(0.059)	(0.064)	(0.058)	(0.056)
Driver5	-0.053	-0.161***	0.056	0.051	-0.075	0.001	-0.056	-0.013
	(0.058)	(0.057)	(0.057)	(0.059)	(0.056)	(0.059)	(0.055)	(0.053)
Driver6	0.209***	0.217***	0.081	0.138**	0.135**	0.160**	0.150***	0.184***
	(0.058)	(0.054)	(0.065)	(0.060)	(0.055)	(0.066)	(0.056)	(0.053)
Driver7	0.028	0.122**	0.082	0.070	0.194***	0.072	0.140***	0.143***
	(0.058)	(0.052)	(0.060)	(0.052)	(0.052)	(0.065)	(0.054)	(0.049)
Bus. plan (0/1)	0.532***	0.165	0.338**	0.229*	0.771***	0.383***	0.566***	0.033
	(0.126)	(0.110)	(0.151)	(0.126)	(0.130)	(0.143)	(0.124)	(0.114)
Exporter (0/1)	-0.130	0.090	0.128	-0.168	0.063	-0.058	-0.108	0.030
	(0.129)	(0.113)	(0.138)	(0.126)	(0.124)	(0.137)	(0.123)	(0.119)
Multisite (0/1)	0.239**	0.254**	0.102	0.172	0.252**	0.379***	0.156	0.049
	(0.121)	(0.117)	(0.141)	(0.130)	(0.128)	(0.142)	(0.121)	(0.118)
Rural (0/1)	0.060	0.102	0.381***	0.368***	0.197	0.303**	0.093	-0.095
	(0.141)	(0.128)	(0.142)	(0.140)	(0.140)	(0.153)	(0.134)	(0.135)
Size: log(Emp)	0.195***	-0.099	0.089	0.070	0.034	-0.059	-0.023	0.055
	(0.068)	(0.065)	(0.076)	(0.069)	(0.070)	(0.081)	(0.067)	(0.065)
Age (baseline: 0 to 5 years)								
6 to 10 years	-0.203	-0.389	-0.182	-0.088	0.392	0.339	0.204	-0.065
	(0.285)	(0.272)	(0.303)	(0.301)	(0.299)	(0.317)	(0.262)	(0.263)
11 to 20 years	-0.259	-0.265	-0.251	-0.010	0.306	0.127	0.120	-0.003
	(0.258)	(0.248)	(0.271)	(0.271)	(0.277)	(0.296)	(0.240)	(0.241)
More than 20 years	-0.284	-0.180	-0.227	0.204	0.089	0.047	0.106	-0.185
	(0.254)	(0.241)	(0.264)	(0.265)	(0.273)	(0.292)	(0.235)	(0.238)
Sector (baseline: 2 manufacturing)								
Primary ABDE	-0.086	0.231	0.271	0.134	0.062	-0.023	-0.043	-0.146
	(0.370)	(0.324)	(0.356)	(0.307)	(0.366)	(0.434)	(0.385)	(0.387)
Construction F	-0.727***	0.154	0.211	-0.286	0.155	0.095	-0.066	-0.134
	(0.275)	(0.226)	(0.275)	(0.285)	(0.260)	(0.291)	(0.268)	(0.245)
Transport, retail and distribution GHI	-0.606***	-0.202	-0.004	-0.235	-0.113	0.004	0.121	-0.061
	(0.173)	(0.150)	(0.186)	(0.163)	(0.171)	(0.194)	(0.160)	(0.156)
Business services JKLMN	-0.494***	-0.054	-0.238	-0.461***	-0.261	-0.134	-0.133	-0.004
	(0.165)	(0.154)	(0.199)	(0.175)	(0.177)	(0.207)	(0.175)	(0.160)
Other services PQRS	-0.256	-0.523***	-0.081	-0.500**	0.059	-0.060	-0.062	-0.048
	(0.192)	(0.196)	(0.246)	(0.216)	(0.205)	(0.243)	(0.199)	(0.190)
Nation (baseline: England)								
Northern Ireland	0.242	-0.147	-0.137	0.122	0.078	-0.026	-0.027	0.193
	(0.152)	(0.132)	(0.176)	(0.142)	(0.150)	(0.195)	(0.147)	(0.130)
Scotland	0.097	-0.307	-0.210	-0.188	-0.055	0.218	-0.239	-0.110
	(0.203)	(0.188)	(0.243)	(0.214)	(0.199)	(0.199)	(0.192)	(0.189)
Wales	0.315	-0.306	0.224	0.087	-0.023	0.129	-0.034	-0.076
	(0.252)	(0.277)	(0.277)	(0.256)	(0.271)	(0.298)	(0.277)	(0.258)
Constant	-2.304***	-1.106***	-2.858***	-2.326***	-2.911***	-2.905***	-2.237***	-1.791***
	(0.344)	(0.323)	(0.400)	(0.373)	(0.378)	(0.413)	(0.340)	(0.326)
Observations	964	964	964	964	964	964	964	964
LR chi2	190.1	187.2	113.5	139.7	212	147.6	143.9	163
Degrees of freedom	23	23	23	23	23	23	23	23
Prob > chi2	0	0	0	0	0	0	0	0
Log likelihood	-408.5	-524.1	-318.5	-401.9	-430.7	-325.4	-463.8	-512.9
Pseudo R-squared	0.208	0.200	0.214	0.170	0.234	0.237	0.168	0.148

Source: ERC Business Futures Survey

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
NZ1- environmental reports or audits; NZ2 - Changed processes or transport/logistics to reduce carbon emissions; NZ3 - Invested in research and development related to the environment; NZ4 - Introduced air pollution monitoring and filtering; NZ5 - Conducted training on environmental matters; NZ6 - Conducted market research related to low carbon products or services; NZ7 - Introduced new low carbon products or services; NZ8 - Switched to more renewable energy.
Driver1 – Environmental regulations or taxes (1/5); Driver2 – Government grants or subsidies (1/5); Driver3 – Customer Demand for low-carbon products or services (1/5); Driver4 – Voluntary agreements within your sector or supply chain (1/5); Driver5 – Availability of external funding from banks (1/5); Driver6 - Improving your image and reputation (1/5); Driver7 – Reducing costs (1/5).

Table 4. Control factors and the probability of adoption of Digital practices, probit coefficients

LABELS	(1) D1	(2) D2	(3) D3	(4) D4	(5) D5	(6) D6	(7) D7	(8) D8	(9) D9	(10) D10
Barrier1	0.243*	0.226*	-0.039	-0.094	0.025	-0.017	-0.119	0.090	0.106	-0.137
	(0.125)	(0.124)	(0.122)	(0.112)	(0.117)	(0.113)	(0.114)	(0.122)	(0.148)	(0.145)
Barrier2	0.221*	0.020	0.134	0.118	0.162	-0.027	0.066	0.448***	-0.140	-0.074
	(0.120)	(0.115)	(0.125)	(0.109)	(0.115)	(0.112)	(0.109)	(0.121)	(0.142)	(0.147)
Barrier3	0.000	0.134	0.177	0.127	0.150	0.059	-0.020	0.083	0.118	0.095
	(0.118)	(0.116)	(0.121)	(0.109)	(0.118)	(0.113)	(0.111)	(0.113)	(0.137)	(0.135)
Barrier4	0.093	0.095	-0.062	-0.098	0.081	0.002	-0.205*	-0.088	-0.069	-0.274*
	(0.117)	(0.117)	(0.124)	(0.111)	(0.116)	(0.113)	(0.114)	(0.116)	(0.146)	(0.149)
Barrier5	0.064	0.123	0.262**	0.034	-0.027	0.175	0.244**	0.121	0.075	0.049
	(0.123)	(0.126)	(0.131)	(0.114)	(0.121)	(0.115)	(0.114)	(0.123)	(0.145)	(0.154)
Barrier6	-0.026	-0.130	0.026	0.086	0.058	0.164	0.081	-0.001	0.245*	0.342**
	(0.116)	(0.117)	(0.121)	(0.111)	(0.114)	(0.112)	(0.113)	(0.114)	(0.147)	(0.133)
Bus.plan	0.251**	0.353***	0.122	0.522***	0.416***	0.416***	0.254**	0.218**	0.206	0.386***
	(0.108)	(0.108)	(0.111)	(0.103)	(0.105)	(0.103)	(0.105)	(0.108)	(0.140)	(0.143)
Exporter	0.258**	0.062	0.147	0.133	0.405***	0.267**	0.165	-0.039	0.318**	0.407***
	(0.116)	(0.117)	(0.121)	(0.109)	(0.116)	(0.110)	(0.109)	(0.112)	(0.141)	(0.133)
Multisite	0.283**	0.196	0.284**	0.064	0.417***	0.159	0.023	0.134	0.007	0.057
	(0.121)	(0.124)	(0.121)	(0.111)	(0.124)	(0.115)	(0.113)	(0.114)	(0.139)	(0.139)
Rural	0.319**	0.168	0.013	-0.125	-0.035	-0.085	-0.128	0.151	-0.183	-0.181
	(0.132)	(0.142)	(0.138)	(0.126)	(0.128)	(0.125)	(0.130)	(0.136)	(0.160)	(0.174)
Size: log(Emp)	-0.070	-0.089	-0.070	0.073	0.176**	0.098	-0.014	-0.077	0.081	0.279***
	(0.064)	(0.065)	(0.066)	(0.060)	(0.069)	(0.062)	(0.060)	(0.063)	(0.078)	(0.075)
Age (*baseline: 0 to 5 years*)										
6 to 10	0.353	-0.423	-0.701**	-0.066	0.023	0.094	-0.232	-0.179	-0.041	0.038
	(0.262)	(0.309)	(0.279)	(0.244)	(0.255)	(0.244)	(0.252)	(0.278)	(0.293)	(0.320)
11 to 20	0.110	-0.313	-0.476*	0.162	0.424*	0.244	-0.188	-0.198	-0.003	-0.119
	(0.238)	(0.291)	(0.263)	(0.225)	(0.241)	(0.229)	(0.234)	(0.262)	(0.272)	(0.299)
> 20	0.116	-0.506*	-0.216	-0.049	0.255	-0.033	-0.119	0.053	-0.379	-0.223
	(0.234)	(0.284)	(0.258)	(0.220)	(0.235)	(0.222)	(0.231)	(0.258)	(0.271)	(0.296)
Broad sector (*baseline: 2 manufacturing*)										
Primary	-0.664**	-0.304	-0.003	0.308	0.657*	0.437	-1.238***	-0.377	0.420	0.304
	(0.334)	(0.336)	(0.376)	(0.326)	(0.390)	(0.353)	(0.366)	(0.343)	(0.401)	(0.453)
Construction	0.077	0.346	0.459	-0.318	0.068	0.140	-0.490**	0.450	0.315	0.408
	(0.250)	(0.251)	(0.283)	(0.255)	(0.251)	(0.247)	(0.239)	(0.279)	(0.310)	(0.295)
Transport, retail and distribution	0.056	0.466***	-0.069	-0.135	-0.406***	0.010	-0.825***	0.030	0.056	0.265
	(0.151)	(0.154)	(0.162)	(0.144)	(0.151)	(0.147)	(0.145)	(0.154)	(0.192)	(0.204)
Business services	-0.009	0.253*	0.154	0.268*	0.343**	0.264*	-0.587***	-0.298**	0.008	0.550***
	(0.152)	(0.150)	(0.166)	(0.145)	(0.163)	(0.150)	(0.146)	(0.152)	(0.191)	(0.198)
Other services	0.099	0.244	0.039	-0.291*	0.157	-0.294*	-1.100***	0.001	0.233	0.221
	(0.183)	(0.187)	(0.192)	(0.174)	(0.184)	(0.176)	(0.187)	(0.189)	(0.230)	(0.256)
Nation (*baseline*: England)										
NI	-0.109	-0.043	-0.034	-0.335***	-0.072	-0.057	0.071	-0.075	0.103	-0.269
	(0.129)	(0.136)	(0.141)	(0.122)	(0.126)	(0.124)	(0.127)	(0.127)	(0.158)	(0.182)
Scotland	0.081	-0.073	0.023	-0.208	-0.141	-0.147	0.491***	0.102	-0.094	-0.097
	(0.203)	(0.197)	(0.206)	(0.176)	(0.192)	(0.175)	(0.180)	(0.198)	(0.249)	(0.253)
Wales	0.027	-0.412*	-0.292	0.133	0.086	-0.452*	0.024	-0.355	0.239	0.043
	(0.248)	(0.236)	(0.248)	(0.232)	(0.225)	(0.236)	(0.239)	(0.236)	(0.278)	(0.302)
Constant	0.157	0.722**	1.072***	-0.679**	-1.006***	-0.566*	0.288	0.603*	-1.765***	-2.686***

	(0.321)	(0.363)	(0.341)	(0.306)	(0.337)	(0.310)	(0.315)	(0.350)	(0.397)	(0.434)
Observations	964	964	964	964	964	964	964	964	964	964
LR chi2	43.68	49.57	41.20	75.20	115.5	74.12	90.63	45.11	29.92	73.19
DF	22	22	22	22	22	22	22	22	22	22
Prob > chi2	0.00388	0.000671	0.00780	9.82e-08	0	1.47e-07	2.67e-10	0.00257	0.120	2.06e-07
Log likelihood	-536	-496	-462.6	-628.7	-550	-607.3	-591.8	-543.2	-312.4	-311.4
Pseudo R-squared	0.0460	0.0591	0.0488	0.0720	0.138	0.0723	0.0790	0.0553	0.0613	0.119

Source: ERC Business Futures Survey
Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
D1 - Website to sell goods or services; D2 - Online marketing and social media; D3 - Accounting or HR software; D4 - CRM system; D5 - Video conferencing; D6 - Cloud computing solutions; D7 - Computer Aided Design(CAD); D8 - Internet of things; D9 - Augmented and Virtual reality; D10 - AI and Machine learning.
Barrier1 – lack of funds / access to finance; Barrier 2 – broadband capacity, Barrier 3 – compatibility with existing equipment; Barrier4 – digital skills, Barrier5 – internal resistance to change/workforce engagement, barrier 6 – cyber risk.

The coefficient estimates are in line with our expectations. Interestingly, barriers to digital technologies do not appear to affect much the probability of adoption of digital technologies with most results being insignificant. In some case, positive and significant coefficient indicate that a barrier does not act as a constraint to digital adoption but on the contrary as a stimulus. However, the main interest of our approach does concern the factors affecting the probability of adoption of net zero and digital practices per se but the relationship between the resulting residuals discussed here after.

5. Complementarities after controlling for firm, industry, and geographic characteristics

Table 5 reports the degree of association between pairs of net zero and digital practices after controlling for a set of firm, industry, and geographic characteristics. As discussed previously, if such association is positive and significant, it indicates the existence of complementarities-in-use between practices.

Table 5. Correlation of residuals - non-parametric Kendall's tau_b correlation

	NZ1	NZ2	NZ3	NZ4	NZ5	NZ6	NZ7	NZ8	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
NZ1	1.00																	
NZ2	**0.09**	1.00																
NZ3	**0.20**	**0.08**	1.00															
NZ4	**0.16**	**0.15**	**0.24**	1.00														
NZ5	**0.33**	**0.11**	**0.21**	**0.18**	1.00													
NZ6	**0.20**	**0.09**	**0.40**	**0.23**	**0.25**	1.00												
NZ7	**0.16**	**0.12**	**0.23**	**0.24**	**0.23**	**0.33**	1.00											
NZ8	**0.16**	**0.10**	**0.12**	**0.14**	**0.14**	**0.22**	**0.16**	1.00										
D1	0.05	**0.06**	0.05	0.05	0.05	0.06	0.04	0.00	1.00									
D2	0.03	0.01	0.04	0.00	0.04	0.05	0.02	0.02	**0.23**	1.00								
D3	0.00	**0.07**	0.02	0.02	0.02	0.01	0.03	-0.02	**0.13**	**0.10**	1.00							
D4	**0.09**	0.05	-0.01	0.00	0.02	0.02	**0.06**	**0.06**	**0.12**	**0.08**	**0.12**	1.00						
D5	0.05	**0.10**	0.00	-0.03	0.04	0.00	0.02	**0.07**	0.04	**0.09**	**0.15**	**0.16**	1.00					
D6	0.03	0.05	0.04	0.03	0.03	0.02	**0.07**	0.05	**0.09**	**0.09**	**0.15**	**0.19**	**0.25**	1.00				
D7	**0.06**	0.03	0.00	0.01	**0.07**	0.04	0.01	0.02	**0.06**	0.05	**0.07**	**0.10**	**0.09**	**0.08**	1.00			
D8	0.00	0.04	0.04	0.05	0.03	0.02	0.04	0.01	**0.14**	**0.09**	**0.17**	**0.06**	0.03	0.05	**0.06**	1.00		
D9	0.04	-0.01	**0.09**	0.01	**0.08**	**0.06**	**0.08**	0.03	**0.06**	**0.09**	0.02	**0.07**	**0.08**	**0.13**	**0.09**	0.03	1.00	
D10	0.01	0.00	**0.06**	0.00	0.03	0.05	0.05	0.02	0.03	0.04	**0.06**	**0.16**	**0.08**	**0.17**	**0.12**	0.01	**0.28**	1.00

Source: ERC Business Futures Survey
Note: In bold **green**, **blue** and **orange** – correlations significant at 0.01 level.
NZ1- environmental reports or audits; NZ2 - Changed processes or transport/logistics to reduce carbon emissions; NZ3 - Invested in research and development related to the environment; NZ4 - Introduced air pollution monitoring and filtering; NZ5 - Conducted training on environmental matters; NZ6 - Conducted market research related to low carbon products or services; NZ7 - Introduced new low carbon products or services; NZ8 - Switched to more renewable energy; D1 - Website to sell goods or services; D2 - Online marketing and social media; D3 - Accounting or HR software; D4 - CRM system; D5 - Video conferencing; D6 - Cloud computing solutions; D7 - Computer Aided Design(CAD); D8 - Internet of things; D9 - Augmented and Virtual reality; D10 - AI and Machine learning

First, the results show that important synergetic interdependencies between net zero practices remain even after controlling for differences in firm, industry, and geographic characteristics. For all pairs of net zero practices, there is a statistically significant association (in bold green) meaning that adopting one net zero practice is not independent of adopting another net zero practice. The intensity of this association varies from one pair of practices to another. For instance, synergetic intensity is the strongest between *market research in low carbon* and *environmental R&D* (with correlation coefficient of 0.40), and *between environmental reports/audits* and *training on environmental matters* (0.33). Hence, we find evidence that SMEs in the UK implement a portfolio of net zero practices simultaneously, this is in line with previous studies (Demirel & Kesidou, 2011). One important implication of this analysis is that it is preferrable to focus on adoption of

complementary net zero practices rather than on single practices in isolation when developing policy instruments to support diffusion of net zero practices.

Second, the results also suggest synergies in digital technologies adoption indicated by positive and significant correlations between residuals (in bold green). The overall picture is less compelling with the intensity of association being on average less important when compared to synergies between net zero practices (the largest proportion of variance in probability of digital adoption is explained by firm and environmental characteristics). However, the results confirm that, even after controlling for a set of factors, the use of E-commerce is associated with online marketing, but also – to a lesser extent – with accounting and HR software, CRM, cloud and IoT. We find that the use of advanced AI / ML technologies is strongly associated with the use AR/VR (coefficient of correlation of 0.28), CRM (0.17) and cloud (0.12). Therefore, to jump to the next curve of digital innovation, a firm needs to build a solid digital foundation. It also suggests that integrated digital solutions responding to needs of SMEs in different business functions may be conductive of a faster digital transformation of 'laggards'.

Finally, we find only small evidence of synergies between net zero and digital technologies with only a handful of pairwise correlation coefficients being positive and significant (in bold orange). Nevertheless, we find, for example, synergies between use of *CRM* and undertaking of *environmental reports and audits*, *switching to renewable energy* and introducing *low carbon products and services*. This suggests an increased pay-off of joint adoption of customer-focused digital systems and practices aiming to reduce, measure and showcase environmental impact, especially to reply to customers' needs and to improve firm's reputation. Firms looking to improve customer's experience by making it more environmentally friendly would benefit from streamlining their back-office processes by digitalising them. There is some evidence suggesting synergies between digitalisation (use of e-commerce, accountancy and HR software, video-conference and collaboration tools) and *changes in production/ processes to reduce carbon emissions*.

We also find synergies between advanced digital technologies such as *AR/VR* and *AI/ML* and *investment in R&D related to the environment*. Although the intensity of the synergetic effects is relatively low, this result is still very important because it showcases potential benefits and future development of digitally enabled eco-innovation in the UK SMEs. The

results also point out on synergies between *AR/VR* and organisational net zero practices, such as *training on environmental matters* and low carbon *market research*.

6. Conclusion

Despite a growing interest in twin transition in SMEs, existing evidence is scarce on the joint adoption of net zero and digital practices. In this study, we explored the patterns of use of net zero and digital practices by UK SMEs. This exploratory analysis provides some interesting results.

First, we find strong evidence of synergies between a range of net zero practices implemented by UK SMEs. This implies that future analysis and policy instruments should consider these complementarities rather than focus on particular net zero practices in isolation. Second, the results also suggest synergies between digital technologies which are, however, less intensive than between net zero practices. Detected synergetic effects indicate that to jump to the next curve of digital innovation SME need to build a solid digital foundation.

Finally, although we find only small evidence of synergies between net zero and digital practices in UK SMEs, the results point out to an increased pay-off of joint adoption of customer-focused digital systems and practices aiming to reduce, measure and showcase environmental impact. Importantly, we find synergies between advanced digital technologies such as *AR/VR* and *AI/ML* and *investment in R&D related to the environment* supporting the view that UK SMEs are already on the path of digitally enabled eco-innovation. Future research is needed to further examine the potential of these synergies by evaluating their impact on productivity, growth and environmental performance.

REFERENCES

Ballot, G., Fakhfakh, F., Galia, F., & Salter, A. (2015). The fateful triangle: Complementarities in performance between product, process and organizational innovation in France and the UK. *Research Policy*, 44(1), 217-232.

Battisti, G., and Stoneman, P. (2010). How innovative are UK firms? Evidence from the fourth UK community innovation survey on synergies between technological and organizational innovations. British Journal of Management, 21(1), 187-206.

BEIS (2020). The Energy White Paper: Powering our Net Zero Future. Available at: <https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future> (accessed 19.12.20).

Demirel, P., and Kesidou, E. (2011). Stimulating different types of eco-innovation in the UK: Government policies and firm motivations. *Ecological Economics*, 70(8), 1546-1557.

European Commission (2020). Communication from the Commission to the European parliament, the European council, the Council, the European Economic and Social Committe and the Committee of the Regions. Europe's moment: Repair and Prepare for the Next Generation. Available at: https://ec.europa.eu/info/sites/default/files/communication-europe-moment-repair-prepare-next-generation.pdf (accessed 18.10.21).

Kesidou, E., and Demirel, P. (2012). On the drivers of eco-innovations: Empirical evidence from the UK. *Research Policy,* 41 (5), 862-870.

Kesidou, E., and Ri, A. (2021). Drivers and Performance of Net Zero practices: Evidence from UK SMEs. ERC Research Paper 95, June 2021.

Kesidou, E., and Wu, L. (2020). Stringency of environmental regulations and eco-innovation: Evidence from the eleventh Five-Year Plan and green patents. *Economics Letters,* 190.

Milgrom, P., and Roberts, J. (1990). Rationalizability, learning, and equilibrium in games with strategic complementarities. *Econometrica: Journal of the Econometric Society*, 1255-1277.

Milgrom, P., and Roberts, J. (1995). Complementarities and fit strategy, structure, and organizational change in manufacturing. *Journal of accounting and economics*, 19(2-3), 179-208.

Ozusaglam, S., Kesidou, E., Wong, C. Y. (2018). Performance effects of complementarity between environmental management systems and environmental technologies. *International Journal of Production Economics*, 197, 112–122.

Ri, A., and Luong, H. M. (2021). Digital readiness, Digital adoption and Digitalisation of UK SMEs amidst the Covid-19 crisis. ERC Research Paper 96, July 2021

The Royal Society (2020). Digital technology and the planet: Harnessing computing to achieve net zero Issued: December 2020 DES7035. Available at: < https://royalsociety.org/-/media/policy/projects/digital-technology-and-the-planet/digital-technology-and-the-planet-report.pdf> (accessed 18.10.21)

ERC
Enterprise Research Centre

Centre Manager
Enterprise Research Centre
Warwick Business School
Coventry, CV4 7AL
CentreManager@enterpriseresearch.ac.uk

Centre Manager
Enterprise Research Centre
Aston Business School
Birmingham, B1 7ET
CentreManager@enterpriseresearch.ac.uk

www.enterpriseresearch.ac.uk