Eco-innovations and digitalisation in Small Medium Enterprises: Does geographical location make the difference?

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Extended Abstract

Background and motivation

The recent policy call to put the "twin transition" – green & digital – at the core of the recovery from the Covid19 crisis (Pilati, 2021), has been revamping previous research on the relationship between the "old" Information and Communication Technologies (ICT) and eco-innovations (Cecere et al., 2014; Antonioli et al., 2018). The new digital technologies of the so-called "Industry 4.0" – spanning from Artificial Intelligence and Big Data, to Additive Manufacturing and Internet of the Things – have been claimed to be "enabling" across the board, also and above all of superior environmental performances at the firm level (de Sousa Jabbour et al., 2018). Indeed, recent studies have shown that, though mainly with respect to few of them, by investing in these digital technologies, firms can increase their propensity to introduce eco-innovations in their production processes and models (Montresor and Vezzani, 2022). However, this research is still at an incipient stage, and many aspects remain to be addressed. One of the most important is for sure represented by the role of the geographical context in which firms are asked to move along the twin transition. As firms are not atomistic agents, but rather part of local/regional systems innovations, through whose embeddedness they acquire resources and capabilities for the twin transition, the geographical location of digitalising and greening firms required to be carefully considered. In particular, echoing as much recent studies on the regional geography of the twin transition (e.g., Cicerone et al., 2019), it is important to investigate whether being located in urban rather than rural areas provide firms with an expected twin-transition prise, which could affect the extent to which the same transition is also cohesive and "just" across territories, as the European recovery plans also recommend.

Following the paper by Faucheux and Nicolaï (2011), the relationship between digitalisation and environmental innovations (EI, henceforth) can be recognised as having a dual nature. On the one hand, EIs can mitigate a series of widely recognised damages (Erdmann et al., 2004; Hilty, 2008; Hilty et al., 2005) deriving from both production and adoption of IT. On the other hand, adoption and development of digital technologies by firms can bring about opportunities to eco-innovate across a wide range of sectors by allowing dematerialization of hardware (Faucheux et al., 2002; Haake and Gueorguievsky, 2010), enhancing more energy and resource efficient production processes (Faucheux and Nicolaï, 2011) and boosting EIs positive effects on labour productivity (Antonioli et al., 2018). Focusing on this latter side of the relationship, it can be argued that the advent of new digital technologies usually associated with the Industry 4.0 paradigm provides SMEs with new channels and opportunities to eco-innovate. In fact, these technologies go beyond mere enhancements in connectivity performances thus entailing broader organizational, production and supply chain changes (Frank et al., 2019). This is also relevant at the regional/geographic level. By leveraging on their general-purpose nature (Bresnahan, 2010), some of the 4.0 technologies can help developing interfaces of pre-existing knowledge in a region thus allowing their novel

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recombination into green innovations (Cicerone et al., 2019; Montresor and Quatraro, 2020; Castellacci et al., 2020). Drawing on the geography of eco-innovation literature and on recent firm studies on the twin-transitions, we thus expect that the location in urban areas favours the eco-innovative impact of digital technologies, and that the correlation between digitalization and eco-innovation should be greater in large than in small towns or cities/villages.

Data and methods

Using micro-data from the EU Flash Eurobarometer 486 on "SMEs, Start-ups, Scale-ups and Entrepreneurship", we test our expectations with respect to a large sample of about 16,000 SMEs across the EU28 for cross-sectional observations over the period 2016-2019. We fully exploit the extensive information contained in this dataset to explore the determinants of the introduction of EIs either in terms of product and process eco-innovations. Among the determinants, specific attention is paid to the adoption of digital technologies, the localization of SMEs and the interplay between these two. As far as digital technologies are concerned, we start by focusing on the adoption of at least one of the Industry 4.0 technologies listed in the questionnaire: Artificial intelligence (e.g., machine learning or technologies identifying objects or persons, etc.), Cloud computing (i.e., storing and processing files or data on remote servers hosted on the internet), Robotics (i.e., robots used to automate processes for example in construction or design, etc.), Smart devices (e.g., smart sensors, smart thermostats, etc.), Big data analytics (e.g. data mining and predictive analysis), High speed infrastructure, and Blockchain. In the second part of our analysis, we also analyse the relationship between the probability of eco-innovating and the firms' choice of bundling the adoption of the previous digital technologies to an increasing extent. The core part of the analysis puts a focus on the role of SMEs' localisation, which the Innobarometer survey at stake discloses for the first time by keeping their anonymity: that is, by refraining from providing their georeferenced address, and by rather asking to the respondents to indicate one of the provided descriptive options for their location. Using this new bit of information, we explore the marginal effect on EIs of the localisation in rural, large and small urban areas and, more importantly, we investigate the significance and sign of the moderation effect that these localisations play on the relationship between digitalisation and EI. Finally, we enrich the picture by distinguishing among different types of eco-innovations – e.g., technological and non-technological ones – and by contrasting the results with those between digitalisation and "standard" (i.e., non eco-) innovations.

To estimate the relationship between EIs and the interplay between digital technologies adoption and SMEs localisation, we implement both bivariate probit models and seemingly unrelated regressions (SUR). These models in fact enable us to take into account SMEs' interrelated decisions concerning the introduction of EIs and the adoption of digital technologies. Even if cross-sectional in nature, results are robust to IV estimation. However, endogeneity tests on our focal regressor (i.e., adoption of digital technologies) fail to reject the null hypothesis thus suggesting that the regressor is exogenous and that other estimators, such as bivariate probit and SUR, should be favoured over IV. In order to reduce unobserved heterogeneity, we also control for a series of confounding factors such as: firm size, firm age, industry, country of establishment and other firms' characteristics (i.e., family-business, part of international group, etc.).

Results

The preliminary results we have obtained and on whose refinements we are still working are pretty interesting. We did expect to find a positive and statistically significant correlation between the adoption of digital technologies and EIs, although this correlation can be weaker for some types of digital technologies as demonstrated in another studies that analyse the extent to which firms' investments in digital technologies enhances their propensity of eco-innovating their production

processes and models (Montresor and Vezzani, 2022). A further expectation concerns the role played by SMEs' localisation. On the one hand, we did expect SMEs located in large and small urban areas to be more likely to adopt digital technologies as compared to those located in rural ones. On the other hand, effects of the interplay between IT and localisation on EIs can prove to be more nuanced. In fact, the general-purpose nature of some Industry 4.0 technologies (AI, KETs and AMTs in particular) is likely to bring about more positive effects in areas with pre-existing knowledge specifically in green technologies (Montresor and Quatraro, 2020).

Our results generally confirm our expectations, but with important nuances in terms of both typologies of eco-innovations (technological vs. non-technological) and kinds and bundles of digital technologies that SMEs adopt, among a detailed list of Industry 4.0 ones that the survey covers. Surprisingly, but in line with some recent studies on the geography of eco-innovation (Martin et al., 2013; Galliano et al., 2017), SMEs located in rural areas display a higher propensity to eco-innovate than in urban ones, notwithstanding their relatively poor adoption of digital technologies. Still, it is the urban nature of a location that positively moderate the eco-innovative impact of digital technologies, as we did expect.

Conclusions and possible implications for policy and further research

These results might have two main implications. From the academic viewpoint, we will provide evidence of the positive relationship between the adoption of Industry 4.0 technologies and green technologies thus filling a gap in the incipient analysis of the twin transition at the firm and at the regional level.

From a policy perspective, this evidence suggests that policy support to help SMEs going digital could also help them going green and facilitate their path towards the twin transition. However, this is context-specific and requires industrial and environmental policies to get combined with regional ones.

Key-words: digital technologies, eco-innovation, twin transition, geographical areas

J**EL Codes**: 030, Q55, R12

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