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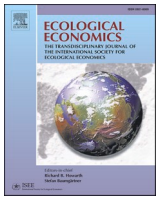

Is digital transformation the Deus ex Machina towards sustainability transition of the European SMEs?

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ABSTRACT

The 2030 Digital Compass aligned with the European Green Deal prioritize transparency through the digital transformation of the European SMEs paving the way to a more sustainable production paradigm. Thus, a twin transition is in motion facilitated by the New Industrial Strategy supporting the adoption of green business strategies across industrial ecosystems. This paper investigates whether the digital transformation and the decision to participate in public procurement as a transparent external funding source support adoption of business actions fostering sustainability transition. Data over more than 20,000 SMEs in the EU-28 over the period 2015–2019 complemented by country-specific attributes towards sustainability and institutional business environment are combined. Econometric results indicate that digital transformation fosters sustainability transition. Although participation in public tenders exerts a positive and systematic effect on the adoption of a sustainability supporting strategy, the two decisions appear independent indicating that SMEs are determined to shift the production paradigm irrespectively. Business operational problems affect but not deter sustainability transition. Business corruption in countries of low levels of sustainability impedes sustainable business actions, yet evidence favors higher transparency. The latter highlights the necessity towards building a coherent although adaptable institutional framework. This study contributes to SDGs 7, 12, 13 and 16.

1. Introduction

European Union faces a twin transition (European Commission, 2020a). The European Green Deal (European Commission, 2019a), the new growth strategy of Europe, targets in making Europe sustainable via carbon-neutrality by 2050. In line with the European objectives and ambitious strategic orientation, global initiatives such as the Sustainable Development Goals Initiative (Assembly, 2015), perceive sustainable production as a major priority to support the transition to a greener and more sustainable future preserving scarce resources, minimizing waste, fostering economic growth, transparency of procedures and ultimately augment human wellbeing.

An integral part of the attempt to serve such endeavor are the Small-Medium Enterprises - SMEs that constitute the backbone of the European production foundation representing most of the business population in the European Union (European Commission, 2020a). The aim is to expand the population of SMEs that adopt a sustainable business strategy i.e., a strategy associated with environmental, technical, economic, or social benefits, as well as to adopt and implement digital technologies to support the sustainability transition (European Commission, 2021; 2020a). In this line, the New Industrial Strategy for Europe (European Commission, 2020d), incentivizes SMEs to adopt business strategies fostering sustainability transition through financing schemes. Specifically, the digital transformation through the Digital Europe Programme brings digital technology to businesses. The green public procurement, to deliver products and services of certain environmental standards, implies a shift to greener production (European Commission, 2008a) while the InvestEU program (European Commission, 2018b) supports collaboration between the public and private sector.

To mobilize the twin transition, the European Commission has launched several programs and initiatives to support the operation of the business in the new era. From the one hand, during the past decade, the sustainability transition has been promoted by the Resource Efficient Europe - Flagship Initiative materialized via the Resource Efficiency Roadmap (European Commission, 2011), the two Circular Economy Action Plans (European Commission, 2015a; 2018a) mirrored in the Climate Action Plan (European Commission, 2019b), echoed in the European Green Deal (European Commission, 2019a) and recently by

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the 2020 Circular Economy Action Plan (European Commission, 2020c). On the other hand, during the last fifteen years or so, there has been a systematic attempt from the European Commission to introduce and promote the acceleration of the digital transformation in tis realm through the EU eGoverment Action Plan (European Commission, 2016a), the Communication on Data, Information and Knowledge Management (European Commission, 2016b), the European Interoparability Framework (European Commission, 2017a). In addition, recently, the European Commission launched the digital transformation the 2030 Digital Compass (European Commission, 2021) to foster prosperity, resilience, and sustainability.

To accelerate digitalization of Europe, the European Industry Strategy (European Commission, 2015b), identified the Digital Innovation Hubs (DIHs) as integral part of the digital transformation to support SMEs overcome potential challenges associated with digital transformation. DIHs through funding from the Digital Europe Programme (European Commission, 2020e) aim to boost competitiveness by stimulating digital transformation at industry level (European Commission, 2018a, 2018b, 2018c) as well as at regional level (European Commission, 2018b, 2018c, 2018d) by providing technical support via a "test the water" scheme before investing. Literature on SMEs' digital transformation through DIHs is becoming a growing wave, especially from the engineering standpoint, as the role of each DIH in offering a distinct and diversified portfolio of actions to support SMEs has been acknowledged (Sassanelli and Terzi, 2022).

Recent studies discuss the pivotal role of DIHs to achieve digital transformation. In this line, Crupi et al. (2020) exploring the mediating role of knowledge brokerage activity on SMEs, external knowledge, and open innovation to investigate whether DIHs act as knowledge brokers to support digital transformation of SMEs. The authors find evidence that DIHs support the development of innovation, collaboration, and knowledge sharing. In a similar line of research, Sassanelli et al. (2020) through a conceptual approach implemented via the Ecosystem-Technology-Business-Skills-Data (ETBSD) reference model, find that DIHs support SMEs to overcome barriers associated with implementation of digitalization. Although literature suggests that performance at firm- as well as country-level could be enhanced through promoting digital transformation (Adomako et al., 2021; You et al., 2020; You et al., 2019) and battle corruption (Haafst, 2017), there is a relative scarcity of studies focusing on the effect of digital transformation on the sustainability transition through the adoption of green business strategies.

Moreover, explaining business behavior via circular economy actions adoption as well as commitment of SMEs to resource efficiency actions is crucial in the quest for sustainability transition. Literature acknowledging the effect of information about funding schemes (Chatzistamoulou and Tyllianakis, 2022a), superior techniques (Ghisetti and Montresor, 2020), integration of new technological paradigms in the business strategy, collaborations, and network development (Chatzistamoulou and Tyllianakis, 2022b), and firm performance (Demirel and Danisman, 2019) has emerged. Recent literature focusing on the twin transition, especially via actions promoting circular economy and digital transformation (e.g., Sassanelli et al., 2021; Rocca et al., 2020; Rosa et al., 2020), has surfaced as well. Nascimento et al. (2018) highlight the influence of digital technologies in the adoption of green strategies while this is further supported by evidence from manufacturing industries also suggesting that technology initiatives such as the "Industry 4.0", foster sustainability transition of the SMEs (Acharya et al., 2019). Digital transformation also refers to the availability of large datasets i.e., big data, to monitor progress towards sustainability transition of the SMEs which also generates challenges firms need to overcome through organizational capabilities change (Jabbour et al., 2020).

All in all, sustainability transition and digitalization constitute cornerstones of the European policy agenda (European Commission, 2021; 2019a) prioritizing the digital transformation, especially of the SMEs. Such being the case, it is of particular interest to explore the effect of digital transformation and transparency of procedures that support such shifts on the decision of the SMEs to adopt business strategies fostering sustainability transition. Therefore, a research gap associated with the investigation the effect of digital transformation and participation of SMEs in funding schemes such as public procurement, as determinants of the decision making process to adopt a business strategy fostering sustainability transition, emerges. Thus, in this paper, we fill this void by developing a conceptual framework to investigate *whether adopting business strategies facilitating sustainability transition are influenced by (i) digital transformation and (ii) the decision to participate in public procurement, as a transparent external funding source.*

The contribution is twofold as it highlights the role of digital transformation as the Deus ex machina, or in other words as the means to pave the way to sustainability transition in conjunction to a transparent institutional framework. To explore the main research question, this study employs micro-level characteristics, such as firm heterogeneity and business operational barriers, as well the macro-level country attributes towards sustainability and institutional coherence such as digital competitiveness and regulation.

Evidence suggests that two forces forge sustainability transition, the digital competitiveness, and the public procurement as a source of transparent external support. Digital competitiveness appears to be crucial in the decision to adopt a business strategy supporting the socio-technical sustainability transition. Findings indicate that firms are affected by operational barriers such as fast changing legislation and complexity of administrative procedures. However, are not deterred towards developing a green business agenda. Business corruption hinders the adoption of a sustainability enhancing business strategy, only in countries of low performance at the sustainable development goals index though. Finally, the macro-environment such as resource productivity, national expenditure on environmental protection as well as a solid institutional base against corruption pave the way towards sustainability transition.

The paper unfolds as follows. Section 2 presents the conceptual framework and research hypotheses, Section 3 describes the material and method, Section 4 includes interpretation of the estimation results, Section 5 fosters discussion on the results while Section 6 concludes the paper.

2. Conceptual framework, operationalization and research hypotheses[1]

The conceptual approach adopted herein is built around the socio-technical transition including changes both at the business model and the technology aspect (Geels, 2018; Geels and Schot, 2010; Grin et al., 2010), considering European policy framework to support such transition as mentioned above. A transition is a long-term process materializing via channels of radical and structural changes of economic systems across the economy structure i.e., from firms to countries. Grin et al. (2010) frame sustainability transition as a "*radical transformation as a response to a number of persistent problems confronting contemporary modern societies*". For SMEs however, such transition entails adoption of decisions mitigating negative impacts of production either on the environment or the society, aspects that are included in sustainable development initiative (United Nations, 2022).

In this paper, the alternation of the business model via adopting strategies with an environmental, social, economic, cultural impact or a combination of those, could be considered as sustainability-enhancing. Thus, sustainability transition, as a dynamic process, includes radical transformation of societal systems as well as the shift towards more sustainable modes of production and consumption (European Commission, 2020b; Markard et al., 2012; Smith et al., 2010). The change of the business institutional environment is captured by measuring a country's

[1] We owe the development of this section to an anonymous reviewer.

capacity and readiness to adopt and explore digital technologies for economic transformation in business, government, and wider society. Such institutional conditions cultivate a business mindset facilitating the implementation of technological advancements fostering digitalization. In conjunction to the alternation of the production paradigm to a more sustainable one via adoption of business actions promoting sustainability, the investigation of the twin transition and its effect on SMEs, becomes possible.

We argue that the decision of the firm to adopt a sustainability enhancing business strategy to achieve the socio-technical sustainability transition is influenced by drivers of the micro (firm-level) as well as the macro (country-level) environment of the firm. Therefore, we formulate a set of research questions to investigate our conceptual narrative. Fig. 1 below illustrates the conceptual framework introduced herein considering the European policy framework to support the sustainability transition and digital transformation. Specifically, SMEs operate within the policy framework provided by the European Union regarding sustainability transition and digital transformation (left-hand side of Fig. 1) shaping the decision-making process to achieve the socio-technical transition (right-hand side of Fig. 1). The socio-technical transition is affected by characteristics of the micro-environment of the firm such as firm heterogeneity and procurement transparency, as well as by the macro-environment including the attitude of the country towards sustainability and institutional framework. The influence of the former is examined through research hypotheses 1 to 3 while the latter is investigated through research hypotheses 4a and 4b, as shown below.

As far as the research hypotheses is concerned, firstly, literature suggests that firm level heterogeneity affects performance (Dosi et al., 2010). Thus, we control for firm level characteristics, such as lack of expertise, difficulty in attaining standards (Ozkan-Ozen et al., 2020; De Jesus and Mendonça, 2018), firm size, turnover as well as cost of environmental action (Chatzistamoulou and Tyllianakis, 2022b), among others, affecting implementation of sustainability enhancing strategies. Such being the case, we form and test the following hypothesis:

H_1: Firm heterogeneity hinders sustainability transition as the latter requires capacity and capabilities that are asymmetric among the firms.

It is also tested whether business operating environment problems such as corruption, fast changing legislation, and complexity of administrative procedures (e.g., Dimakopoulou et al., 2022; Chatzistamoulou and Tyllianakis, 2022a), affect willingness to engage in a sustainability-promoting strategy. Stated formally:

H_2: The business environment problems and barriers faced by firms hinder the process of adopting strategies fostering sustainability transition.

In addition, it is investigated whether the characteristics of the public procurement process such as the participation of the firm in those and whether firms perceive the former as distinctively corrupted, through the following hypothesis:

H_3: The perception firms have on the characteristics of the public procurement processes influence the decision to adopt strategies fostering sustainability transition.

We test for the effect of the macro-environment via factors related to the *country's attitude towards sustainability (H_{4a}),* such as the resource productivity, and environmental protection expenditure of the country, as literature suggests that those affect the adoption of sustainability-enhancing business strategies (Chatzistamoulou and Tyllianakis, 2022b; Chatzistamoulou and Tyllianakis, 2022a). We also explore the effect of factors associated with the *country's attitude towards enhancing the coherence of the institutional production environment (H_{4b}),* such as the digital competitiveness, corruption, and regulations e.g., Amankwah-Amoah et al. (2021).

More precisely, literature highlights the influence of the regulatory framework (Chatzistamoulou and Koundouri, 2022; García-Quevedo et al., 2020) as empirical findings suggest that corruption affects environmental performance (Desai, 1998) and resource allocation (Amankwah-Amoah et al., 2021; Amankwah-Amoah et al., 2019) projecting on sustainability patterns e.g., energy consumption (Arminen and Menegaki, 2019), among others. Furthermore, there is evidence on the effect of corruption in Europe (Teichmann et al., 2020), across the globe such in BRICS and NEXT (Sinha et al., 2019), in African countries (Leal and Marques, 2021; Sulemana and Kpienbaareh, 2018) and in China (Wang et al., 2020; Chen et al., 2018) as well. Studies also consider the combination of corruption and development level (Akhbari and Nejati, 2019). However, there is scarcity of studies to explore the effect of digital transformation as part of the institutional block of factors. Thus, we form and test the following research hypotheses:

H_{4a}: The country attitude towards sustainability such as resource productivity and eco-innovation, influences the decision of the firm to adopt strategies fostering sustainability transition.

H_{4b}: The country attitude towards building a coherent institutional business environment such as digital transformation, transparency to battle corruption as well as regulation, influences the decision of the firm to adopt strategies fostering sustainability transition.

3. Material & methods

3.1. Material

The paper is benefited by data on 23,464 European Small-Medium Enterprises (onwards SMEs) drawn from the Flash Eurobarometer 428 (7996 SMEs), 457 (7746 SMEs) and 482 (7722 SMEs) titled "Businesses' Attitude Towards Corruption in the EU" covering the EU-28 member states[2] in 2015, 2017 and 2019 respectively (European Commission, 2016c, 2017b, 2020f). To the best of our knowledge, this is the first paper exploring all the available information from those series of cross-sectional surveys on this topic provided by the European Commission. The unit of analysis is firms in the EU-28 across the years considered.

The dataset includes micro-level variables affecting a firm's decision to adopt a green business strategy i.e., actions associated with environmental, technical, or social benefits through permits[3] from the public authorities. Those variables could be categorized into the (i) firm-specific heterogeneity such as firm size, and turnover change, (ii) aspects of the operating environment considered as barriers in the country of operation by the firms, such as business corruption and legislation change and (iii) characteristics of the public procurement processes such as perceived corruption in the procurement process nationally and firm participation in such processes.

In addition to the firm-level variables, macro-level data is collected through various specialized databases. Such data is related to country-specific characteristics that might affect the decision of the firm to include in its business strategy actions promoting sustainability transition through preserving the environmental quality, social and institutional coherence. Macro-level variables have been included to mirror discrepancies in productivity and environmental priorities across European countries, as evidence indicates that sustainability asymmetries emerge among the EU-28 (Chatzistamoulou and Koundouri, 2021). Specifically, we categorize the country specific characteristics into the attitude of the country towards (i) sustainability transition, and (ii) building a coherent business institutional environment.

The former category includes data on resource productivity, renewable energy use, environmental protection expenditure and eco-

[2] Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Rep., Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithouania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Rep., Slovenia, Spain, Sweden, United Kingdom. As the UK follows the European directives and report the relevant data at the time span, it has been included in the dataset.

[3] Permits, at the firm level, promoting the green transition include whether a firm is interested in obtaining either (i) environmental permits including waste and water treatment, (ii) permits related to vehicles usage or (iii) state aid, social, structural funds permits.

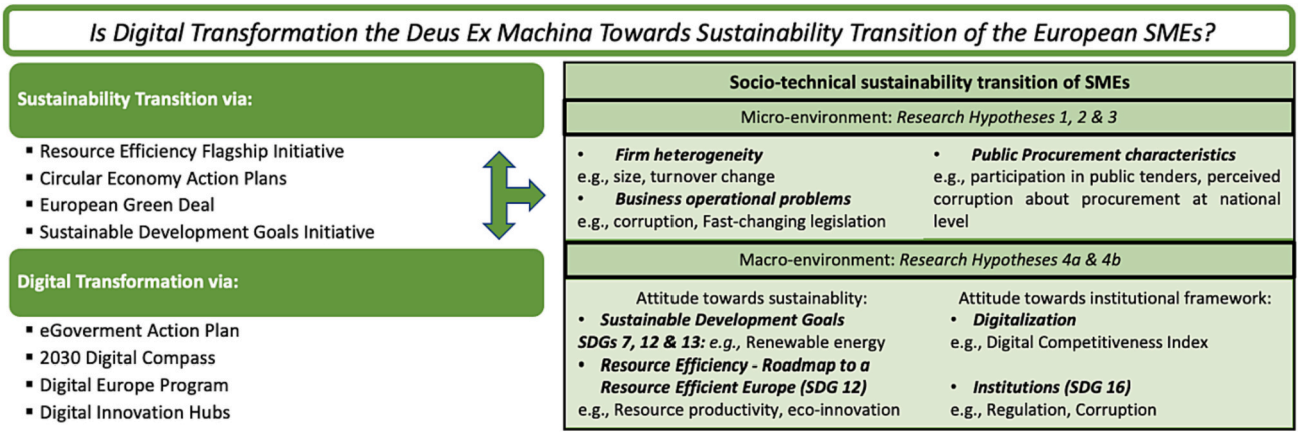

Fig. 1. Conceptual framework of the European SMEs' sustainability transition and digital transformation.
Source: Chatzistamoulou, N. (2023). Is digital transformation the Deus ex Machina towards sustainability transition of the European SMEs?, *Ecological Economics.*

innovation. Data is collected through Eurostat Europe 2020 section (Eurostat, 2022), and has been included to mirror productivity and institutional discrepancies. Data on the eco-innovation index is collected via the Eco-Innovation Observatory-DG Environment. The Eco-innovation index is based on theory-driven indicators capturing the process of eco-innovation (Park et al., 2017), embracing five thematic areas.[4] It measures a country's eco-innovation performance and thus is an aspect of the country attitude towards sustainability and green growth (Chatzistamoulou and Tyllianakis, 2022a; Binswanger, 2001). Data on the sustainable development goals index capturing each economy's performance in achieving the seventeen sustainable development goals, is collected through the 2019 Europe Sustainable Development Report, jointly produced by the Sustainable Development Solutions Network-SDSN and the Institute for European Environmental Policy-IEEP (SDSN and IEEP, 2019).

As regards the latter category, this is the first paper that benefits from hand-collected data on the World Digital Competitiveness (WDC) measuring a country's capacity and readiness to adopt and explore digital technologies for economic transformation in business, government, and wider society. It is a multi-faceted index embracing three main factors such as knowledge (capturing the intangible infrastructure necessary for learning and discovery dimensions of technology), technology (quantifying the landscape of developing digital technologies) and readiness (examines the level of preparedness of an economy to assume its digital transformation).[5] By construction, the WDC assumes that digital transformation takes place primarily at enterprise level but also at government and society levels. It is produced by the IMD World Competitiveness Center (IMD World Competitiveness Centre, 2019). The Corruption Perceptions Index, reflecting how corrupt a country's public sector is perceived to be, is produced by the Transparency International (Transparency International, 2022), and its appropriateness has been acknowledged by the literature (Sinha et al., 2019; Dincer and Fredriksson, 2018; Lisciandra and Migliardo, 2017; Harring, 2014; Kaufmann et al., 2010; Svensson, 2005). Data on regulation is collected and produced by the Fraser Institute as integral part of measuring the functionality of each economy, and thus the production environment of the firm (Fraser Institute, 2019). Table 1 below provides the descriptive statistics, sources and a brief description of the variables used.

[4] Eco-innovation Inputs, Activities and Outputs, Socio-economic Outcomes, Resource efficiency Outcomes.

[5] The Digital Competitiveness includes 9 sub-factors such as Talent, Training and Education Scientific Concentration for Knowledge, Regulatory Framework, Capital and Technological Framework for Technology, Adaptive Attitudes, Business Agility, and IT Integration for Future Relatedness. In total, it is comprised by 52 criteria.

Therefore, this study contributes to the Sustainable Goals 7 (Affordable and Clean Energy), 12 (Responsible Consumption and Production), 13 (Climate Action) and 16 (Strong Institutions) by exploring their effect on the promotion of sustainability-enhancing business actions adoption.

3.2. Method

In this paper, we investigate *whether adopting business strategies facilitating the sustainability transition are influenced by (i) digital transformation and (ii) the decision to participate in public procurement, as an external funding source.*

We consider that the strategy of the firm is influenced by the decision to adopt a strategy promoting sustainability transition and the decision to participate in public procurement or tenders to ensure funding to support such production paradigm shift. Therefore, we address the simultaneity of the decisions, or in other words, the potential selection bias in case firms participate in public procurement to fund such socio-technical transition. Neglecting for such potential selection could cause bias to the estimation results (Heckman, 1979; Gronau, 1974).

The outcome variable (*EnvSocPerm*) refers to whether a firm adopts strategies facilitating sustainability transition i.e., whether the firm express interest in obtaining permits with environmental, technical or social benefits over the last year, while the binary selection variable corresponds to whether a firm has participated in a public tender or procurement process (*PubProcPart*). The appropriate method is to employ *the binary response probit model with sample selection* (Van de Ven and Van Praag, 1981), to provide consistent and asymptotically efficient estimates for all the parameters of interest. The model can be described using the binary outcome and selection equations as follows:

Binary outcome equation :

$$\begin{aligned} EnvSocPerm_i = {} & \alpha_0 + \boldsymbol{\beta FirmHeterogeneity}_i + \boldsymbol{\gamma BusinessBarriers}_i \\ & + \delta_1 PubProcPart_i + \boldsymbol{\zeta MacroEnvironment}^{SustainabilityAttributes} \\ & + \boldsymbol{\theta MacroEnvironment}^{BusEnvAttributes} + \epsilon_i \end{aligned} \tag{1}$$

Binary selection equation :

$$\begin{aligned} PubProcPart_i = {} & a_1 + \boldsymbol{\mu FirmHeterogeneity}_i + \\ & \lambda_1 PerceivedCorruption_i^{PubProcNationally} \\ & + \lambda_2 PerceptionsCorruptionIndex_i + u_i \end{aligned} \tag{2}$$

The parameters to be estimated are α_0, α_1, δ_1,λ_1,λ_2,$\boldsymbol{\beta,\gamma,\zeta,\theta}$ and $\boldsymbol{\mu}$ while ϵ_i *and* u_i are the disturbance terms of the binary outcome and selection

Table 1
Variables, sources and descriptive statistics.

Variables	Brief description & units of measurement	Frequency			Source
Firm-level characteristics		**2015**	**2017**	**2019**	
Interest in acquiring a permit for a business strategy promoting sustainability	Interest in acquiring permit leading to environmental, economic or social benefit	32.00%	31.86%	32.06%	
Firm size categories	1–9 Full-time eq. employees (category 1)	56.03%	56.71%	56.49%	
	10–49 Full-time eq. employees (category 2)	21.29%	22.17%	24.28%	
	50–249 Full-time eq. employees (category 3)	16.20%	15.19%	14.09%	
Turnover change	Turnover decrease over the past two years	23.21%	16.58%	14.31%	
Firm age	Years the company is in business (mean/sd)	21.23/ 26.96	23.08/ 23.97	32.37/ 97.14	European Commission
Business operational problems	Corruption	34.55%	34.96%	33.44%	EU Open Data Portal
	Complex administrative procedures	55.68%	55.68%	56.50%	
	Fast changing legislation and policies	59.63%	59.02%	58.75%	
	Inadequate infrastructure	38.86%	41.83%	41.92%	
	Tax rates	59.00%	57.09%	57.19%	
	Access to financing	37.81%	33.10%	31.97%	
	Perceived corruption in public procurement nationally	49.61%	47.92%	48.76%	
Public procurement characteristics	Firm participation in public tenders/procurement	9.90%	30.31%	30.74%	
Country-specific attributes		Mean (Standard Deviation)			
Attitude towards sustainability					
Resource productivity	Purchasing power standard (PPS) per kilogram	1.81 (1.13)	1.80 (1.13)	2.10 (1.00)	Eurostat – Europe 2020 section
Renewable energy use	Share of renewable energy in gross final energy consumption (percentage)	20.73 (11.56)	21.38 (11.70)	22.95 (11.65)	Eurostat
Environmental protection expenditure	National expenditure on environmental protection (% of Gross Domestic Product)	2.02 (0.56)	1.87 (0.62)	1.91 (0.58)	
Eco Innovation index	Eco-innovation performance across the EU-28 (number)	86.36 (28.50)	92.45 (28.17)	94.74 (31.28)	Eco-Innovation Observatory & Eurostat, DG Environment
Attitude towards business environment					
Digital Competitiveness Ranking	Digital Competitiveness Ranking (number) Digital Economy and Society Index for 2015*	0.48 (0.10)	73.62 (13.68)	71.99 (13.46)	IMD World Competitiveness Center
Corruption Perceptions Index	Reflects how corrupt a country's public sector is perceived to be (number)	65.33 (15.11)	64.71 (13.97)	64.14 (14.19)	Transparency International
Regulation	Reflects regulatory restraints affecting economic the freedom (number)	7.83 (0.46)	7.90 (0.43)	7.88 (0.38)	Economic Freedom-Fraser Institute

Note: Frequencies of the realization of the variable of interest while numbers and parentheses refer to the average and standard deviation of the country-specific characteristics.

equation respectively.

4. Results

Table 2 below presents the estimation results[6] (coefficients and standard errors) of the binary response model with (binary) selection for all the waves considered *to explore whether digital transformation is the* Deus ex machina *to achieve sustainability transition*. The lower part of Table 2 however, indicates that the Wald test of independence of the two decisions does not differ significantly from zero. The latter pinpoints towards the existence of no selection effect (i.e., the two decisions are perceived as independent across all the years considered). Such being the case, there is sufficiently enough evidence to support that the decision to adopt a business strategy fostering the socio-technical sustainability transition and the participation to public procurement to support such actions are considered as self-determining by the firms, given the sample and period.

Thus, we proceed with the estimation of a binary response probit model including participation in the public procurement process as a driver of the firm's decision to adopt a business strategy fostering sustainability. Table 3 presents the coefficients and standard errors of the models considered while Table 4 presents the average marginal effects. The information criterion provided at the lower part of Table 3 indicates that digital competitiveness contributes more to explaining the decision to adopt a sustainability-enhancing strategy, so the focus is on those models (DCI models). However, the models including the corruption perception index (CPI) are also discussed and linked with the literature.

Focusing on the models including the digital competitiveness (DCI) for the years considered, regarding the characteristics of the micro-level environment of the firm and particularly the firm level heterogeneity, findings are in line with existing literature indicating that heterogeneity matters (Tsekouras et al., 2016, 2017; Dosi et al., 2010). Specifically, size matters as relatively small firms appear to be reluctant in adopting a green strategy and this is also the case for those experienced turnover decrease (Chatzistamoulou and Tyllianakis, 2022a; Demirel and Danisman, 2019). The impact of relatively small firms on firm performance has also been documented in the innovation literature e.g., Garrido-Prada et al. (2021). Therefore, firm asymmetries hinder the sustainability transition (*Hypothesis 1 is not rejected*).

As far as the business operational problems faced by firms are

[6] A set of robustness tests has been performed to validate the findings. First, the sample has been partitioned based on the average performance of each country on the Sustainable Development Goals index, SDGi, (Sachs et al., 2021), in two distinct sub-groups, that of low SDG index and of high SDG index levels for both Digital Competitiveness and Corruption Perceptions Index cases. Then, for each group, we re-estimate the models. Then, further validation includes robustness checks for each of the six industries [(i) Energy, mining, oil and gas, chemicals, (ii) Healthcare and pharmaceutical, (iii) Engineering and electronics, motor vehicle manufacturing, (iv) Construction and Building, (v) Telecommunications and Information technologies and (vi) Financial services, banking, and investment] included in the sample. In all cases, no significant changes occurred; thus, the empirical findings are adequately valid. Robustness checks for the whole sample in 2019 appear in the Appendix (Figure A1, Table A1). Additional evidence including estimations for the rest of the years considered as well as estimations by industry are available upon request.

Table 2
Estimation results of the sample selection model: Coefficients & Robust Standard Errors.

Outcome eq. (OE): Adoption of business strategies fostering socio-technical sustainability transition						
Selection Eq. (SE): Participation in public procurement process						
	2015		2017		2019	
Drivers	OE	SE	OE	SE	OE	SE
Micro-environment						
Firm-specific heterogeneity						
Decreased turnover	−0.021	0.077	0.082	0.018	−0.140	−0.070
	(0.011)	(0.047)	(0.078)	(0.043)	(0.087)	(0.046)
Size category 1 (small firms)	−0.238	0.011	−0.865***	−0.752***	−0.788***	−0.723***
	(0.255)	(0.105)	(0.238)	(0.069)	(0.172)	(0.070)
Size category 2 (relatively small firms)	−0.067	0.309***	−0.425***	−0.276***	−0.416***	−0.322***
	(0.270)	(0.106)	(0.134)	(0.071)	(0.126)	(0.072)
Size category 3 (large firms)	0.035**	0.167	−0.239**	−0.130*	−0.151	−0.071
	(0.273)	(0.109)	(0.116)	(0.073)	(0.115)	(0.075)
Firm age	0.001	0.001	0.002	0.002***	0.017	0.056
	(0.002)	(0.001)	(0.001)	(0.001)	(0.034)	(0.17)
Sector effects (NACE II)	Yes	Yes	Yes	Yes	Yes	Yes
Business operational problems						
Corruption	0.251**	–	−0.003	–	−0.082	–
	(0.113)		(0.067)		(0.066)	
Complexity of administrative procedures	0.182	–	0.051	–	0.207***	–
	(0.113)		(0.066)		(0.065)	
Fast-changing legislation	0.035	–	0.116*	–	0.140**	–
	(0.111)		(0.066)		(0.065)	
Inadequate infrastructure	−0.049	–	0.023	–	0.062	–
	(0.102)		(0.062)		(0.061)	
Tax rates	0.111	–	0.080	–	0.058	–
	(0.111)		(0.064)		(0.062)	
Access to financing	0.035	–	−0.159**	–	−0.036	–
	(0.103)		(0.065)		(0.064)	
Procurement characteristics						
		0.434***		−0.166***		−0.058
Perceived corruption in public procurement nationally	–	(0.046)	–	(0.034)	–	(0.036)
Public procurement participation	–	–	–	–	–	–
Macro-environment						
Attitude towards sustainability						
	−0.234**		−0.119**		−0.230***	
Resource productivity	(0.093)	–	(0.047)	–	(0.052)	–
	−0.011***		−0.019***		−0.019***	
Renewable energy use	(0.006)	–	(0.004)	–	(0.004)	–
	0.001		0.006***		0.001	
Eco Innovation index	(0.003)	–	(0.002)	–	(0.002)	–
	0.250**		0.336***		0.193	
Environmental protection expenditure	(0.098)	–	(0.051)	–	(0.051)	–
Attitude towards business environment						
	3.530****		−0.001		0.011**	
Digital Competitiveness Ranking	(0.979)	–	(0.005)	–	(0.005)	–
	−0.088		−0.060		−0.043	
Regulation	(0.120)	–	(0.089)	–	(0.088)	–
		−0.009		0.001		−0.001
Corruption Perceptions Index	–	(0.002)	–	(0.001)	–	(0.001)
Model information						
Obs Selected	784		2273		2331	
Obs Non-Selected	7.096		5292		5336	
Obs	7880		7565		7667	
Model *p*-value	0.000		0.000		0.000	
Bayesian Information Criterion	5973.076		11,534.79		11,853.49	
p-value of Wald test of indep. Eqns. (rho = 0) i.e., selection is exogenous	0.759		0.909		0.934	

Notes: (i) all models include constants, (ii) coefficients and robust standard errors in parentheses, (iii) stars indicate statistical significance at 1% "***", 5% "**", 10% "*", and (iv) the symbol "+" indicates a very small number.

concerned, it is documented that firms determined in implementing a sustainability enhancing agenda do not seem to be deterred by potential obstacles such as the complexity of procedures and fast-changing legislation. However, evidence pinpoints that environmental regulations in the EU-context could potentially infuse uncertainty to SMEs (Daou et al., 2020). In line with recent literature on the effect of corruption on business performance (Gaganis et al., 2019), findings indicate a negative, yet pale, effect of corruption on the decision to adopt a sustainability enhancing strategy providing support for the "sand the wheels" hypothesis, while for firms in countries of low sustainability levels the effect is systematically stronger (see Table A1 in the Appendix).

Moreover, access to finance and credits does not seem to be a major obstacle for the implementation of a sustainability enhancing agenda. The European Commission through its funding schemes, such as the InvestEU programme (European Commission, 2018b) aiming at the

Table 3
Estimation results of the probit model: Coefficients & Robust Standard Errors.

Dependent variable: Adoption of business strategies fostering socio-technical sustainability transition						
	2015		2017		2019	
Drivers	DCR	CPI	DCR	CPI	DCR	CPI
Micro-environment						
Firm-specific heterogeneity						
Decreased turnover	−0.041	−0.030	−0.008	0.015	−0.146***	−0.138***
	(0.038)	(0.038)	(0.044)	(0.044)	(0.047)	(0.047)
Size category 1 (small firms)	−0.756***	−0.786***	−0.743***	−0.759***	−0.689***	−0.699***
	(0.067)	(0.068)	(0.072)	(0.071)	(0.073)	(0.072)
Size category 2 (relatively small firms)	−0.397***	−0.407***	−0.371***	−0.371***	−0.385***	−0.391***
	(0.070)	(0.070)	(0.073)	(0.073)	(0.074)	(0.073)
Size category 3 (large firms)	−0.192**	−0.193**	−0.173**	−0.171**	−0.180**	−0.181**
	(0.070)	(0.070)	(0.075)	(0.074)	(0.077)	(0.076)
Firm age	0.000+	0.000+	0.001**	0.001	0.031**	0.028
	(0.001)	(0.001)	(0.001)	(0.001)	(0.018)	(0.017)
Sector effects (NACE II)	Yes	Yes	Yes	Yes	Yes	Yes
Business operational problems						
Corruption	−0.037	−0.014	−0.013	0.021	−0.043	−0.047
	(0.038)	(0.038)	(0.039)	(0.039)	(0.039)	(0.039)
Complexity of administrative procedures	0.129***	0.137**	0.067*	0.086**	0.109***	0.104***
	(0.037)	(0.037)	(0.039)	(0.039)	(0.038)	(0.038)
Fast-changing legislation	0.112***	0.127***	0.118***	0.113***	0.151***	0.144***
	(0.037)	(0.037)	(0.039)	(0.039)	(0.039)	(0.038)
Inadequate infrastructure	−0.040	−0.014	0.005	0.004	0.081**	0.078**
	(0.036)	(0.036)	(0.037)	(0.036)	(0.037)	(0.036)
Tax rates	0.059*	0.067*	0.098***	0.102***	0.047	0.044
	(0.035)	(0.035)	(0.037)	(0.037)	(0.036)	(0.036)
Access to financing	0.056	0.058*	−0.031	−0.029	0.036	0.026
	(0.035)	(0.035)	(0.038)	(0.038)	(0.037)	(0.037)
Procurement characteristics						
	−0.080**	−0.035	−0.018	−0.022	−0.023	−0.022
Perceived corruption in public procurement nationally	(0.034)	(0.035)	(0.036)	(0.036)	(0.036)	(0.036)
	0.313***	0.316***	0.432***	0.430***	0.427***	0.430***
Public procurement participation	(0.052)	(0.052)	(0.035)	(0.035)	(0.035)	(0.035)
Macro-environment						
Attitude towards sustainability						
	−0.119***	−0.144***	−0.247***	−0.023***	−0.279***	−0.270***
Resource productivity	(0.025)	(0.026)	(0.027)	(0.002)	(0.029)	(0.029)
	−0.009***	−010***	−0.024***	−023***	−0.020***	−0.019***
Renewable energy use	(0.102)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)
	0.002	−0.001	0.006***	0.004***	0.004***	0.004***
Eco Innovation index	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	0.184***	0.171***	0.293***	0.289***	0.268***	0.265***
Environmental protection expenditure	(0.031)	(0.030)	(0.029)	(0.028)	(0.030)	(0.031)
Attitude towards business environment						
	1.235***		0.009***		0.012***	
Digital Competitiveness Ranking	(0.277)	–	(0.003)	–	(0.003)	–
	0.095**	0.058***	0.006	−0.061***	−0.084	−0.080***
Regulation	(0.042)	(0.039)	(0.052)	(0.046)	(0.052)	(0.050)
		0.019***		0.016***		0.008***
Corruption Perceptions Index	–	(0.002)	–	(0.002)	–	(0.002)
Model information						
Obs	7880	7880	7459	7609	7559	7709
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000
BIC	9087.421	9006.837	8295.289	8406.128	8560.356	8696.017

Notes: (i) all models include constants, (ii) coefficients and robust standard errors in parentheses, (iii) stars indicate statistical significance at 1% "***", 5% "**", 10% "*", and (iv) the symbol "+" indicates a very small number.

collaboration of public-private funding, and the recently introduced Digital Europe Programme (DIGITAL) promoting transparency in business operation, supports the sustainability transition of SMEs (*Hypothesis 2 is rejected*). It should also be mentioned that searching for funding of green business strategies could be a cumbersome process for firms detaining implementation (Cecere et al., 2020).

The block of variables related to public procurement matters in decision making regarding the adoption of a green business strategy, in line with the previous finding that corruption has a weak effect on the adoption of a sustainability enhancing agenda (*Hypothesis 3 is not rejected*). Participation in public procurement processes appear to exert a positive impact on SMEs' sustainability transition. This is in line with the literature acknowledging it is a public administration tool in reaching the sustainability goals and proves to be quite efficient in Europe (Rosell, 2021). Moreover, evidence is in favor of the effect of (green) public procurement as a tool to promote the sustainability transition (Sönnichsen and Clement, 2020; Sparrevik et al., 2018).

Shifting the attention to the macro-level characteristics, and specifically the country-specific attributes towards the sustainability, it is noticeable that those exert a systematic effect on the chance to adopt a sustainability enhancing action (*Hypothesis 4a is not rejected*). Particularly, a negative effect of resource productivity on the decision to adopt a sustainability enhancing business action promoting sustainable production is documented, in line with the literature (Robaina et al., 2020), while a rebound effect surfaces (Vélez-Henao et al., 2020; Liu et al., 2019). However, literature appears to be mixed regarding both effects

Table 4
Average Marginal Effects of the probit models.

	2015		2017		2019	
	DCR	CPI	DCR	CPI	DCR	CPI
Micro-environment						
Firm-specific heterogeneity						
Decreased turnover	−0.013	−0.010	0.002	0.005	−0.046***	−0.043***
	(0.012)	(0.012)	(0.013)	(0.013)	(0.015)	(0.015)
Size category 1 (small firms)	−0.241***	−0.248***	−0.228***	−0.231***	−0.215***	−0.217***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.022)	(0.022)
Size category 2 (relatively small firms)	−0.127***	−0.129***	−0.114***	−0.113***	−0.120***	−0.122***
	(0.022)	(0.022)	(0.022)	(0.022)	(0.023)	(0.023)
Size category 3 (large firms)	−0.061**	−0.061***	−0.053**	−0.052**	−0.056**	−0.056**
	(0.022)	(0.022)	(0.023)	(0.022)	(0.024)	(0.024)
Firm age	0.000 + *	0.000+	0.000 + *	0.000+	0.010*	0.009
	(0.000+)	(0.000+)	(0.048)	(0.000+)	(0.005)	(0.005)
Business operational problems						
Corruption	−0.012	−0.005	0.004	0.006	−0.013	−0.015
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Complexity of administrative procedures	0.041***	0.043***	0.021*	0.026**	0.034**	0.032***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Fast-changing legislation	0.036***	0.040***	0.036	0.034***	0.047***	0.045***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Inadequate infrastructure	−0.013	−0.004	0.002**	0.001	0.025**	0.024**
	(0.012)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Tax rates	0.019*	0.021**	0.030***	0.031***	0.015	0.014
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Access to financing	0.018	0.018*	−0.010	−0.009	0.011	0.008
	(0.011)	(0.011)	(0.012)	(0.011)	(0.011)	(0.012)
Procurement characteristics						
	−0.025**	−0.011	0.005	0.011	−0.007	−0.007
Perceived corruption in public procurement nationally	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
	0.100***	0.100***	0.132***	0.132***	0.133***	0.134
Public procurement participation	(0.017)	(0.016)	(0.011)	(0.010)	(0.011)	(0.010)
Macro-environment						
Attitude towards sustainability						
	−0.038***	−0.046***	−0.076***	−0.078***	−0.087***	−0.084***
Resource productivity	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)
	−0.003***	−0.003***	−0.007***	−0.007***	−0.006***	−0.006***
Renewable energy use	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	0.000+	0.000+	0.002***	0.001***	0.001***	0.001***
Eco Innovation index	(0.000^{+})	(0.000+)	(0.000^{+})	(0.000+)	(0.000^{+})	(0.000+)
	0.059***	0.054***	0.090***	0.088***	0.084***	0.082***
Environmental protection expenditure	(0.010)	(0.009)	(0.009)	(0.008)	(0.009)	(0.009)
Attitude towards business environment						
	0.394***		0.003***		0.004***	
Digital Competitiveness Ranking	(0.038)	–	(0.001)	–	(0.001)	–
	0.030**	0.018	0.002	−0.019	−0.026	−0.025
Regulation	(0.013)	(0.012)	(0.016)	(0.014)	(0.016)	(0.016)
		0.006***		0.005***		0.003***
Corruption Perceptions Index	–	(0.001)	–	(0.001)	–	(0.001)
Obs	7880	7880	7459	7609	7559	7709

Notes: (i) all models include constants, (ii) average marginal effects and robust standard errors in parentheses, (iii) stars indicate statistical significance at 1% "***", 5% "**", 10% "*", (iv) the symbol "+" indicates a very small number.

(Mavi and Mavi, 2019; Mikulčić et al., 2019; Ilić and Nikolić, 2016). Eco-innovation performance exerts a positive and systematic effect on sustainability transition, indicating that boosting any of its components would mitigate technological asymmetries among the member states (Bianchi et al., 2020; Caravella and Crespi, 2020). Environmental protection expenditure at the national level, cultivates a positive climate affecting firm decision-making towards actions supporting the sustainability transition. The literature acknowledges that green investment increases firm performance (Chen and Ma, 2021; Alam et al., 2019) while recent evidence indicates that country level governance characteristics also have a positive impact (Alam et al., 2020).

The coherence of the operational business environment at the country-level is also crucial in influencing the decision of the firm to adopt business strategies fostering sustainability transition (*Hypothesis 4b is not rejected*). This is in line with the institution-based strand suggesting that institutions of the country determine firm behavior and strategic choices (Elango and Dhandapani, 2020), as those influence a country's resource allocation (Amankwah-Amoah et al., 2021; Amankwah-Amoah et al., 2019). Precisely, the digital competitiveness level of the country appears to be a major driver of the sustainability transition as it exerts a strong, positive, and systematic influence on the decision to engage in green business strategies. Regarding regulation, it appears that the stringency of regulation at the country level would exert no systematic effect on the decision of the firm to adopt strategies promoting sustainability transition, providing evidence against the Porter Hypothesis (Porter and Van der Linde, 1995). Nevertheless, literature on the effect of regulation on sustainability and green growth appears to be inconclusive as adverse effects have also been recently documented (He et al., 2020; Lundgren and Zhou, 2017).

Furthermore, the strong effect of digital competitiveness on the adoption of a business strategy fostering sustainability transition reflects the commitment to the implementation of the Europe's Digital Strategy through the Digital Strategy Implementation Plan by 2022 (European Commission, 2018e). Such endeavor has been supported since 2005 by

previous policies and directives that aimed at accelerating the digital transition such as the EU eGoverment Action Plan (European Commission, 2016a), the Communication on Data, Information and Knowledge Management (European Commission, 2016b), the European Interoperability Framework (European Commission, 2017) and more recently by the 2030 Digital Compass (European Commission, 2021).

Turning the spotlight on the models examining the effect of the corruption perceptions index (CPI), it should be mentioned that literature indicates that the effect of corruption at the firm-level performance leads to mixed findings giving rise to the "grease the wheels" and "sand the wheels" hypotheses. The "grease the wheels" hypothesis, considers corruption as necessary evil arguing about its positive effect on firm performance suggesting that in the presence of insufficient institutions, it provides a way out of demanding bureaucratic rigidities and inflexibility (Hanousek and Kochanova, 2016; Wang and You, 2012). The "sand the wheels" hypothesis indicates that corruption and bribery have a negative effect on firm performance (Şeker and Yang, 2014) as well as at the country environmental performance (Lisciandra and Migliardo, 2017). The latter suggests a negative effect of corruption on firm employment growth of private firms, as opposed to the public ones, especially for larger ones (Jiang and Nie, 2014) while a positive effect emerges for smaller firms (Sheng et al., 2019). Moreover, in the innovation and growth literature a positive effect of corruption on growth is outlined (Paunov, 2016; De Rosa et al., 2015; Vial and Hanoteau, 2010). There are also cases of mixed results on performance (Sharma and Mitra, 2015).

However, in line with Gaganis et al. (2019) who study SMEs in the EU-25 along with country-specific characteristics such as business environment indicators, evidence presented herein indicates that higher transparency promotes sustainability enhancing business actions. Thus, findings are in favor of the "sand the wheels" hypothesis. In addition, Dincer and Fredriksson (2018) find that that corruption affects the stringency of environmental regulation whereas Fu and Jian (2021) document a corruption positively affect innovation diffusion under environmental stringency in developing countries. As a final remark, Bahoo et al. (2020) provide an extensive systematic review of the literature on corruption in the international business realm mapping seven streams of research such as the effect of corruption on firms and the political environment.

5. Discussion

Boosting sustainability transition has become of paramount priority for governments. Such being the case, herein, we discuss the role of digital transformation and green public procurement as policy instruments. Results indicate that digital competitiveness exerts a systematic effect on the decision of the firm to alter its production paradigm to a more sustainable one. This brings to the forefront the significance of the digital transformation in supporting the sustainability transition as facilitated by the 2030 Digital Compass (European Commission, 2021). The latter, according to the European Commission, evolves around four cardinal points, setting solid digital targets for digital skills, digital infrastructure, businesses, and public services. Moreover, considering the diverse identity of each firm, the SME Strategy for a sustainable and digital Europe (European Commission, 2020a) promotes the sustainability transition through capacity building and digitalization, improving market access by reducing regulatory burden as well as improving access to financing. The latter is in line with the New Industrial Strategy for Europe (European Commission, 2020d) supporting the growth of SMEs across the value chain of industrial ecosystems.

Access to the appropriate skill set, know-how as well as technological or digital capabilities is the workhorse to support such transition. In case such endeavor cannot be served internally, governments need to outsource the expertise required. This is done by procuring such activities to accomplish their objectives in an efficient manner without wasting resources, given binding budget constraints, environmental regulation, and timely delivery. In public procurement, governments using tax funds rely on the private sector e.g., SMEs to deliver. From the perspective of the firm, the latter implies that public procurement acts as an external funding source, to support and to a certain extent incentivize the adoption of green strategies. In this paper, findings indicate that there are two forces in the service of sustainability transition; the digital competitiveness to ensure transparency and the fact that public procurement processes act as the instrument to guide such transition through funding sustainable production.

Indeed, the above results (Tables 3 and 4), document that firms participate in public procurement to fund their transition to sustainable production. In this line, the green public procurement (GPP) can be instrumental in addressing as well as mitigating environmental problems. The GPP literature highlights the positive effect of such scheme as a facilitator of sustainability transition (Sönnichsen and Clement, 2020; Sparrevik et al., 2018). Moreover, evidence indicates that procurement of funding has an intensifying effect in the business agenda (Greco et al., 2017), in line with our findings. GPP is supported by the European Commission (European Commission, 2008a) as it guarantees that budgets are well spent, and resources are efficiently allocated to minimize environmental damage. It complements other policy directives paving the way towards sustainability transition through resource efficiency (European Commission, 2011) and competitive economy through sustainable production (European Commission, 2008b), leading to products with environmental benefits (European Commission, 2003) adding value to the supply chain by following the principles of circular economy (European Commission, 2015a).

Funding schemes such as the InvestEU program (European Commission, 2008b), fund business strategies fostering sustainability transition via the joint efforts of private and public sector to establish partnerships (PPPs) to exchange knowledge. Recent evidence suggests that PPPs promote sustainability (Ferronato et al., 2019). Furthermore, the Digital Europe Programme (DIGITAL), with a budget of €7.5 billion is a new funding scheme focused on bringing digital technology to businesses, citizens and public administrations and is part of the long-term Multiannual Financial Framework 2021–2027. Thus, the transparency of the procurement process, which in the case examined herein is perceived as functional based on the findings, is crucial both for monitoring reasons and ensuring that the environmental criteria in the delivery of the products or services are aligned with the quality standards.

From a managerial perspective, SMEs seem to be aware of the benefits in pursuing a greener business agenda as it is thought of as means to adapt in the new era and secure funding to support such shift. Such being the case, literature shows firms that adopt actions promoting sustainability transition such as actions to save energy, water and/materials among others, should engage in a constantly evolving trajectory around the development of new methods and ways to combine stages of production (Bodas-Freitas and Corrocher, 2019). To this end, in line with our findings, "*access to funding and the provision of specialized advice in supporting the implementation of sustainability principles are more important for firms that already implement such actions* (Bodas-Freitas and Corrocher, 2019). Thus, information plays a crucial role in developing and remain committed in a sustainability promoting business agenda, especially for funding tools (Chatzistamoulou and Tyllianakis, 2022a) and implementation of new technological paradigms (Chatzistamoulou and Tyllianakis, 2022b).

From a policy perspective, evidence shows that firm decision-making in adopting actions towards sustainability transition, is affected by the digitalization level of the business environment, that is the macro-environment meaning that institutions are also crucial in boosting the twin transition. This connects the dots regarding the direction of the European as well as national policy making. From the one hand aid regarding the funding schemes to bypass operational obstacles i.e., through awareness of the role of DIHs is necessary while on the other reshaping public structure through digitalization of operations appears

to be a key contributor.

6. Conclusions

The twin transition European Union is going through is in motion. The European Green Deal has set digital transformation as a priority to shape a more sustainable European economy. To explore the effect of digital transformation on the sustainability transition, this paper employs data provided by the European Commission focusing on European SMEs in the EU-28 from 2015 to 2019 to study whether the digital transformation drives sustainability transition, among others. Moreover, we test for decision dependence between participation in public procurement and adopting a sustainability enhancing business strategy. Beyond the aspects of firm's behavior, such as firm-specific heterogeneity and business operational obstacles, the dataset is enriched with time-varying country-specific characteristics to explore the attitude of each member state towards sustainability such as resource productivity and eco-innovation as well as with business environment characteristics such as digital competitiveness and regulation.

The paper contributes to the literature by providing evidence that (i) digital competitiveness systematically fosters the sustainability transition on the European SMEs and (ii) the decision to participate in public procurement is independent to the adoption of a sustainability enhancing strategy indicating that SMEs are determined to shift the production paradigm irrespectively of the public funding. We also document that lower corruption and a coherent institutional background appear to facilitate such transition. Findings indicate that European firms, although face operational problems such as complexity of administrative procedures and fast changing regulation, are not deterred in adopting a sustainability-enhancing strategy.

This paper provides evidence on the positive effect of digital transformation in promoting sustainability transition and this effect appears to be systematic across the robustness checks conducted. We provide evidence in favor of the "sand the wheels" hypothesis, as corruption exerts a negative yet systematic influence on the decision to adopt a sustainability enhancing business strategy particularly in countries with low performance at the sustainable development goals index. Competing for public tenders is considered as an external attractive source of funding, however SMEs appear to be determined to adopt a sustainability enhancing strategy. The macro-environment attributes towards sustainability exert a systematic influence on the business agenda. Based on the sustainable development goals index, SMEs in countries below the European average appear to respond differently both at the micro- and macro-level characteristics.

All in all, the conceptual framework of the paper, applicable across relatable datasets, highlights that building a modern, resilient, adaptable, flexible, and coherent institutional framework that integrates technological relatedness, incentivizes sustainability transition. Nevertheless, conclusions should be drawn cautiously as this study comes with limitations. Should more data becomes readily available by official sources, a wider time window along with green growth indices could benefit the approach to further enrich the stock of knowledge in the literature.

Declaration of Competing Interest

The authors declare that there is no conflict of interest.

Data availability

Data will be made available on request.

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Appendix A. Appendix

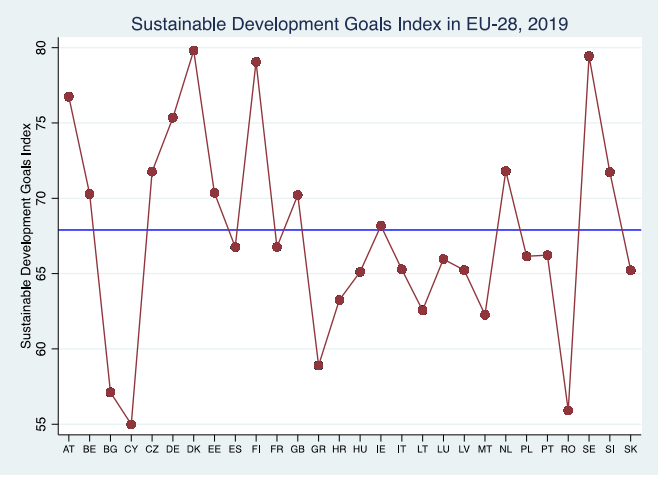

Fig. A1. Sustainable development goals index in the EU-28 in 2019.
Source: Chatzistamoulou, N. (2023). Is digital transformation the Deus ex Machina towards sustainability transition of the European SMEs?, *Ecological Economics*.

Table A1
Average marginal effects by sustainable development goals index performance.

Dependent variable	Adoption of business strategies fostering sustainability transition			
	Digital Competitiveness Ranking		Corruption Perceptions Index	
Micro-environment	Low SDG index	High SDG index	Low SDG index	High SDG index
Firm-specific heterogeneity				
Decreased turnover	−0.040**	−0.048**	−0.037**	−0.047**
	(0.018)	(0.024)	(0.018)	(0.024)
Size category 1 (small firms)	−0.185***	−0.238***	−0.184***	−0.239***
	(0.033)	(0.031)	(0.032)	(0.031)
Size category 2 (relatively small firms)	−0.089***	−0.142***	−0.088***	−0.142***
	(0.033)	(0.032)	(0.033)	(0.032)
Size category 3 (large firms)	−0.042	−0.051	−0.037	−0.051
	(0.035)	(0.034)	(0.034)	(0.034)
Firm age	−0.004	0.021***	−0.004	0.021***
	(0.008)	(0.008)	(0.008)	(0.008)
Sector effects (NACE II)	Yes	Yes	Yes	Yes
Business operational problems				
Corruption	−0.025*	0.018	−0.021	0.019
	(0.015)	(0.022)	(0.014)	(0.022)
Complexity of administrative procedures	0.035**	0.036**	0.031**	0.036**
	(0.016)	(0.018)	(0.016)	(0.018)
Fast-changing legislation	0.043**	0.042**	0.037**	0.042**
	(0.017)	(0.018)	(0.016)	(0.018)
Inadequate infrastructure	0.019	0.043*	0.017	0.044**
	(0.015)	(0.018)	(0.014)	(0.018)
Tax rates	0.001	0.021	0.004	0.021
	(0.016)	(0.017)	(0.015)	(0.017)
Access to financing	0.007	0.035*	0.004	0.035*
	(0.015)	(0.020)	(0.014)	(0.020)
Procurement characteristics				
	−0.013	−0.014	−0.011	−0.013
Perceived corruption in public procurement nationally	(0.014)	(0.018)	(0.014)	(0.018)
	0.154***	0.101***	0.153***	0.101***
Public procurement participation	(0.014)	(0.017)	(0.013)	(0.017)
Macro-environment				
Attitude towards sustainability				
	−0.101***	−0.068***	−0.093***	−0.074***
Resource productivity	(0.022)	(0.023)	(0.022)	(0.017)
	−0.003**	−0.006***	−0.003**	−0.007***
Renewable energy use	(0.001)	(0.002)	(0.001)	(0.002)
	0.001*	0.003***	0.001	0.002***
Eco Innovation index	(0.001)	(0.001)	(0.001)	(0.001)
	0.081***	0.074***	0.077***	0.077***
Environmental protection expenditure	(0.025)	(0.015)	(0.024)	(0.014)
Attitude towards business environment				
	0.005***	−0.001		
Digital Competitiveness Ranking	(0.001)	(0.003)	–	–
	−0.103***	0.026	−0.080***	0.021
Regulation	(0.023)	(0.032)	(0.021)	(0.031)
			0.004***	0.000+
Corruption Perceptions Index	–	–	(0.022)	(0.001)
Obs	4200	3359	4350	3359

Notes: (i) all models include constants, (ii) average marginal effects and robust standard errors in parentheses, (iii) stars indicate statistical significance at 1% "***", 5% "**", 10% "*", (iv) the symbol "+" indicates a very small number.

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