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Technology adoption of small and medium-sized enterprises and performance in European countries: A cross-country panel cointegration analysis

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ABSTRACT

Objective: The objective of the article is to explore the impact of the new technology adoption on the performance of small and medium-sized enterprises (SMEs) at the country level.

Research Design & Methods: The authors modelled the effect of technology adoption (TA) on SMEs' market and sustainability performance by using the dynamic ordinary least squares regression technique. The analysis used a sample of 12 EU countries from 2008 to 2021. Regional specificities of the Baltic and Central European countries were introduced. We obtained a novel database from the European Union's SME Performance Review indicators.

Findings: The results show that TA positively affects both market and sustainability performance in European SMEs at the country level. This impact is larger for market performance than for sustainability performance. Moreover, the long-run equilibrium relationships between TA and market performance demonstrate a positive effect in Central European countries and a negative effect in Baltic countries. Moreover, the impact of TA on sustainability performance proves negative for the joint group of new member countries consisting of Baltic and Central European states unlike for old member countries.

Implications & Recommendations: The findings suggest the adoption of a more strategic perspective among SMEs regarding TA. Furthermore, the study offers policy recommendations aimed at facilitating the green transformation of new member countries.

Contribution & Value Added: The effects of TA on market and sustainability performance have not yet been examined by applying an econometrically sophisticated analytical sequence on a panel dataset of countries' SMEs. For policymakers, the findings demonstrate that environmentally friendly technologies, through enhancing sustainability performance, can be a solid pillar that undergirds a widespread green economic transition.

Article type:	research article
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INTRODUCTION

Small and medium-sized enterprises (SMEs) play a significant role in the economies of European Union (EU) countries, employing nearly two-thirds of the workforce and contributing slightly over half of the economic value added (Eurostat, 2022a). Previous research indicates that innovation and technology adoption (TA) positively impact company performance. Notwithstanding this, a major unaddressed controversy in the SME literature is that the latter studies were conducted either at the firm level in the form of case studies (Mustafa & Yaakub, 2018; Jalil *et al.*, 2022) or on a specific industry or set of industries (Pinto, 2020; Rosli & Sidek, 2013). Scholarly studies have not specifically examined the effectiveness of TA in relation to national-level SME performance (Zamani, 2022), and they have failed to provide actionable insights for policymakers, primarily due to the absence of comprehensive inter-country-level databases (Xu *et al.*, 2021).

Technology adoption may increase SMEs' market performance and reduce the latter's environmental impact – which the European Green Deal calls for – with SMEs playing a crucial role (Muller *et al.*, 2022). Firm-level studies have highlighted the beneficial role of TA in sustainability performance in the areas of environmental efficiency (Yacob *et al.*, 2019), data-driven analytics (Chen *et al.*, 2020), technology-based sustainable practices (Gangwar *et al.*, 2023), and supply chain transparency (Maqsood *et al.*, 2022). However, studies that examine this relationship at the country level, with SMEs as the central focus of empirical investigations, are lacking.

The article investigates the long-term relationship between technology adoption and the market and sustainability performance of the SMEs of EU-member OECD states. Moreover, it seeks to analyse how this relationship is influenced by the innovation potential of the region where the country's SMEs are located.

For this purpose, we assembled a novel database that adopted the SME Performance Review (SPR) indicators compiled by the EU. The article applies Eurostat's definition of an SME: An enterprise with fewer than 250 employees, with annual turnover not exceeding EUR 50 million, and/or whose annual balance sheet total does not exceed EUR 43 million (European Commission, 2003). We conducted the analysis on a sample of 12 EU member states and OECD countries from 2008 to 2021. For a more detailed analysis aligned with our research objectives, we developed distinct measures for Baltic and Central European countries, in addition to those for a group comprising older, innovation-leading EU members.

Using a distinctive longitudinal country-level database for SMEs, this article affirms the presence of the positive impact of TA on the market performance of SMEs at the state level. Moreover, the long-run equilibrium relationships revealed that these effects vary between the two groups of newer member countries, eliciting a positive effect for Central European countries and a negative effect for Baltic countries. Our study affirms the positive impact of TA on the sustainability performance of European SMEs at the country level. Interestingly, this effect proves negative for the combined group of new member countries consisting of Baltic and Central European states, unlike the old ones. Furthermore, TA has a stronger impact on market performance than sustainability performance, underscoring the significance of governmental and corporate policies that foster technology-driven environmental sustainability efforts. As part of the managerial recommendations aimed at maximising the positive effects of TA on sustainability performance for the newer EU Member States with lower innovation levels, this study underscores the significance of bolstering their SMEs' external partnerships, licensing strategies, dynamic capabilities, and establishing of an advanced network of R&D centres, drawing inspiration from Western European models.

Another significant contribution of this article is methodological. To ensure valid inferences using the estimated coefficients, we implemented a comprehensive sequence of econometric analyses, making our research unique in business economics. This included investigating cross-sectional dependence across countries (see Pesaran, 2015; Croissant & Millo, 2019), assessing the presence of unit roots (Croissant & Millo, 2019), examining the existence of long-run relationships in the panel series using a panel cointegration test (Pedroni, 1999), and estimating long-run relationships using dynamic ordinary least square estimators (Saikkonen, 1991).

Following the introduction, Section 2 will discuss previous contributions to understanding the relationship of TA with both market and sustainability performance and develop hypotheses based on the literature. Section 3 will give an overview of the data and methodology applied. Section 4 will present the sequence of econometric analyses and their results. Section 5 will define the contributions, note limitations, and suggest further research avenues.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

TA by SMEs and its Effect on Market Performance

Technology adoption significantly improves SMEs' market performance by leveraging business process activities (Guo *et al.*, 2017).

Firstly, TA is positively associated with firms' efficiency and productivity (Cieślik *et al.*, 2016). Information-processing theory suggests that TA increases the efficiency of information processing inside an organisation. Technology improves business information gathering, analysis, and transmission, improving decision-making and performance (Srinivasan & Swink, 2018). Secondly, TA reduces firms' costs by optimising processes, eliminating errors, and minimising the physical resources required (Kumar & Ayedee, 2021). Technology diffusion resulting from TA also enhances productivity, lowers prices, and improves production processes (Fuentelsaz *et al.*, 2009; Greve & Seidel, 2014).

Thirdly, TA can increase firms' competitive advantage (Sebrek, 2015; 2020; Wadood *et al.*, 2022). Following the resource-based view, TA provides valuable resources associated with distinctive capabilities that improve firm performance and competitive advantage over rivals (Niehm *et al.*, 2010). Fourthly, TA may enhance the customer experience by helping implement customer relationship management systems, personalising communication, and providing timely support (Salah *et al.*, 2021).

Fifthly, TA strengthens SMEs' agility and adaptability; it enables businesses to quickly adapt to changing market conditions and customer demands (Teece, 2007). For instance, with the right information and communication technology (ICT) tools, companies can modify processes, launch new products or services, and respond to market trends. Finally, adopting new technologies frequently leads to innovation and creates new opportunities. Notably, technologies like blockchain and virtual reality can disrupt industries and create novel business models (Mustafa & Yaakub, 2018; Semenova *et al.*, 2023).

Scholars have extensively studied technology adoption in SMEs' business processes. Torrent-Sellens *et al.* (2022) concluded from a study of a large sample of Spanish SMEs during the period 1991-2016 that there is a total factor productivity gap between companies which implement ICT investments, R&D activities, and product innovation, and those who do not or fail at this. Other studies have employed a cross-sectional analysis. Jalil *et al.* (2022) found a positive relationship between innovation capabilities and SME performance among 611 Malaysian SMEs (involving cost-effectiveness, product performance, stakeholder satisfaction, and improved enterprise image). These results are in line with the findings of Mustafa and Yaakub (2018) and Octavia *et al.* (2020) for Indonesia, and the results of Chege *et al.* (2020) for Kenya. Thus, few studies have examined the impact of TA on firm performance using longitudinal cross-country samples.

The findings and mechanisms identified in earlier research at lower units of analysis indicate a positive association between TA and SME market performance. Therefore, we formulated the following hypothesis:

H1: In the context of SMEs at the country level, a positive relationship exists between TA and market performance.

TA by SMEs Impacting Sustainability Performance

Scholars have been increasingly interested in SMEs' sustainability performance. In line with the claims of stakeholders (Marcon Nora *et al.*, 2023; Flammer & Kacperczyk, 2016) and institutional theories (Berrone *et al.*, 2013), there is increasing external pressure on firms for TA aligned with sustainability goals to meet the expectations of stakeholders concerned with environmental and social issues.

Moreover, TA can exert a profound influence on the sustainability performance of both individual firms and entire countries. Until recently, SMEs considered sustainability an expense. However, evidence now indicates that sustainability can be valuable for organizations and can strengthen the firm's value and contribute to stable financial and company performance (Ye *et al.*, 2022; Fatemi *et al.*, 2018; Pinto, 2020). Several mechanisms can be identified that show how TA can affect firms' sustainability performance. Firstly, in accordance with the eco-efficiency theory (Czerny & Letmathe, 2017), by implementing green technologies, SMEs can increase their environmental efficiency; they can minimise the by-products of wastes, decrease energy consumption and reduce greenhouse gas emissions.

Secondly, by leveraging data analytics, businesses can gain insights into resource usage, identify inefficiencies, and develop targeted sustainability strategies (Chen *et al.*, 2020). Thirdly, TA can drive innovation in sustainable practices, products, and services. Technologies like the Internet of Things, artificial intelligence, and data analytics can optimise resource usage, enable predictive maintenance, and foster sustainable innovation (Gangwar *et al.*, 2023; Pappas *et al.*, 2018). Finally, TA is considered a dynamic capability that enables firms to proactively respond to changing environmental conditions and capitalise on sustainability-related opportunities (Dangelico *et al.*, 2017).

Several studies have examined the effects of SMEs' technology adoption on sustainability at a single-country level. Based on an examination of 350 Pakistani manufacturing SMEs, Maqsood *et al*. (2022) concluded that clean innovation technology contributes to sustainable production and consumption and supports SME performance. After examining 260 Malaysian manufacturing SMEs, Yacob et al. (2019) found that energy management, water conservation, and waste management technologies are related to environmental sustainability. Hossain *et al.* (2020), who surveyed 220 Bangladeshi manufacturing SMEs, stated that environmental technological adoption positively relates to sustainable green practices. The literature review demonstrates that adopting new can influence SMEs' market performance and play a vital role in intensifying sustainability performance. However, no previous study has examined the relationship between TA and sustainability performance at the national level using a cross-country comparison of the SME population. Therefore, we hypothesised:

H2: In the context of SMEs at the country level, a positive relationship exists between TA and sustainability performance.

Regional Effects

Contingency theory underscores the significance of contextual circumstances in shaping the relationship between TA and performance. This theory places substantial emphasis on the necessity of aligning TA with the specific requirements and characteristics of the national industrial context to enhance performance (Ahmed *et al.*, 2020; Bhatia & Kumar, 2023).

In the contemporary business landscape, the relationship between TA and firm performance is a multifaceted phenomenon influenced by the regional context within which firms operate (Filippetti & Guy, 2020; Xu *et al.*, 2021). This study asserts that the effectiveness of TA in enhancing firm performance is contingent upon the innovation potential of the region where a country's SMEs are situated. Specifically, innovation-leading regions comprising a group of countries can potentially enhance the positive relationship between TA and firm performance. Conversely, this relationship may be weakened or attenuated in regions with lower innovation potential:

H3a: In the context of SMEs at the country level, the positive relationship between TA and market performance is expected to be stronger in innovation-leader regions and weaker in lower innovation regions.

H3b: In the context of SMEs at the country level, the positive relationship between TA and sustainability performance is expected to be stronger in innovation-leader regions and weaker in lower innovation regions.

RESEARCH METHODOLOGY

Data and Variables

This study considers data from 2008 to 2021 from 12 OECD countries, *i.e.* Austria, Belgium, the Czech Republic, Denmark, Estonia, Germany, Hungary, Latvia, Lithuania, Netherlands, Poland, and Sweden. We took data from the SME performance review (SPR) indicators set by the European Commission. The scoreboard of indices employs quantitative indicators that cover dimensions relevant to SME performance and presents them in accordance with the Small Business Act and its conceptual framework

(De Pedraza Garcia & Anastasis, 2022). All our variables can be found in the SPR database. We briefly explained its origins and data collection methods alongside dependent or independent variables.

The econometrical analysis involves two dependent variables: the market performance and sustainability performance of the SMEs within a specific country. The former (MARKET_PERF) is measured by 'sales of new-to-market and new-to-firm innovation (in % of turnover),' which information originally comes from Eurostat's community innovation surveys (CIS). National authorities conduct CIS among domestic SMEs. The aggregation is also conducted by national authorities in accordance with Eurostat's recommendations and under its tight control (Eurostat, 2022b). The latter (SUSTAIN_PERF) was created using factor analysis (FA) implemented in the *psych* package in *R*. Nine sustainability and environmental variables were used for that. The Eurobarometer surveys on SMEs and green markets (European Commission, 2022) provided the data for the m_1-m_5 variables [m_1: SMEs that have taken resource-efficiency measures (in %), m_2: SMEs that have benefited from public support measures for their resource-efficiency actions (in %), m_3: SMEs that offer green products or services (in %), m_4: SMEs with a turnover share of more than 50% generated by green products or services, m_5: SMEs that have benefited from public support measures for their production of green products (in %)]. The environmental protection expenditure dataset (Eurostat, 2022c) contained the m_6 (SME investment in equipment and plant for pollution control) and m_7 (SME investment in equipment and plant linked to cleaner technology) statistics. Data for all nine sustainability and environmental variables were acquired through direct communication with the sampled SMEs, including personal visits, telephone interviews, web-based interviews, and self-administered questionnaires, followed by validation of the results by Eurostat and their publishing at the country level. We processed all data using Eurostat's metadata quality assessment methodology (European Commission, 2023). We used OECD's green growth indicators (2022) to measure the m_8 (environmental technologies as a proportion of all technologies) and m_9 (CO_2 productivity) variables. These indicators are measured at the country level, not specifically for SMEs. However, these indicators are listed in SPR and may be seen as appropriate indicators for measuring SME performance.

We conducted dimension reduction in two steps. Firstly, we ran FA (details available upon request), which suggested reducing the original nine variables into three: m_1, m_3, and m_9. Secondly, we reran FA considering only these three variables. This recommended extracting only one factor, which measures the sustainability performance of the SMEs, explains 99.77% of the total variance, and is denoted in this study as SUSTAIN_PERF.

We assessed the covariate TA (TECH_ADOP) using the item 'new and growing firms can afford the latest technology,' which is part of the National Expert Survey (NES). We recorded responses on a Likert scale ranging from one to five (one – very bad, five – very good). At least 36 national and regional experts per country fill out NES every two years. Then, harmonisation is conducted centrally to obtain reliable and comparative indicators (Global Entrepreneurship Monitor, 2022). As a control variable, we considered the output gap (OUTPUT_GAP) defined as the GDP per capita of a given country relative to the GDP of Germany (Eurostat, 2023). Previous studies have already used a similar measure (*e.g.* Mendi, 2007).

Table 1 shows the panel series and dummy variables used in the analysis. Panel series include the two dependent variables (MARKET_PERF, SUSTAIN_PERF), the covariate TECH_ADOP and the control variable OUTPUT_ GAP. We created dummy variables for regions to capture the effect of the new EU Member States (NEW_EU _MEMB_D), Baltic (BALTIC_D) and Central European (CENT_EUR_D) regions. According to the European Innovation Scoreboard, these countries have less robust national innovation systems than their Western European counterparts. Following Mendi (2007) and Li *et al.* (2022) missing data are interpolated using the nearest observations.

Table 2 reports the descriptive statistics of the panel series and dummy variables. The total number of observations for each variable was 168 whereby it is a balanced panel embracing the 12 European Union and OECD member countries for the examined 14 years. Among these 12 countries, three were Baltic and three – Central European ones that joined the EU in 2004.

Table 1. Description of variables

Variable	Description
Panel-series	
MARKET_PERF	Market performance is defined as the sales of goods and services that are new to the market and new to the firm as a proportion of turnover.
SUSTAIN_PERF	Sustainability performance created using FA.
TECH_ADOP	New and growing firms can afford the latest technology (Likert scale 1-5).
OUTPUT_GAP	GDP per capita of a given country relative to the GDP of Germany.
Dummy variable	
NEW_EU_MEMB_D	Dummy variable for new EU members: Estonia, Latvia, Lithuania, Hungary, Czech Republic and Poland.
BALTIC_D	Dummy variable for Baltic countries: Estonia, Latvia and Lithuania.
CENT_EUR_D	Dummy variable for Central European countries: Hungary, Czech Republic and Poland.

Source: own study.

Table 2. Descriptive statistics (n=168)

Variable	Mean	Median	Standard deviation	Minimum	Maximum
Panel-series					
MARKET_PERF	10.263	10.426	3.452	1.422	18.668
SUSTAIN_PERF	0	-0.0601	0.882	-1.861	1.803
TECH_ADOP	2.287	2.243	0.358	1.666	3.817
OUTPUT_GAP	-9 058	-8 305	14 307.6	-28 055	14 199
Dummy variable					
NEW_EU_MEMB_D	0.5	-	0.5	0	1
BALTIC_D	0.25	-	0.43	0	1
CENT_EUR_D	0.25	-	0.43	0	1

Source: own study in R.

Model Specification

We analysed the impact of the TA of the SMEs on their performance in two specifications. The first one (1) explores the long-run relationship between TA (TECH_ADOP) and market performance (MARKET_PERF) using the econometric model:

$$\text{MARKET\_PERF}_{it} = \beta_0 + \beta_1 \text{ TECH\_ADOP}_{it} + \beta_2 \text{ OUTPUT\_GAP}_{it} + \varepsilon_{it} \quad (1)$$
$$i = 1, \dots, N = 12 \quad \text{(country)} \qquad t = 1, \dots, T = 14 \quad \text{(time)}$$

in which i represents the cross-sectional units (in this study, countries) and t is the time index.

We further examined the impact of TA on market performance by creating a dummy variable for new EU Members States (NEW_EU_MEMB_D) that we further divided into Baltic (BALTIC_D) and Central European countries (CENT_EUR_D). We then formed TECH_ADOP as an interaction variable with each of these dummies.

The second model explored the long-run relationship between TA and sustainability performance using a similarly structured model.

RESULTS AND DISCUSSION

We investigated long-run relationships using a four-stage procedure. The first stage evaluated the presence of cross-sectional dependence across units – in our context countries – using four tests: (a) the Lagrangian Multiplier (LM) test; (b) the Scaled version of the Lagrangian Multiplier (SLM) test; (c) the Bias-Corrected and scaled Lagrangian Multiplier (BCLM) test, and (d) the CD test. The tests are implemented in *plm* package in *R*. The second stage explores the presence of unit roots. Based on the positive evidence of the presence of cross-sectional dependence, we used the Cross-sectionally augmented Im, Pesaran and Shin (CIPS) test. The CIPS, implemented in *plm* package in *R*, belongs to the second generation of unit root tests capable of detecting panel unit roots under conditions of cross-sectional dependence. In the third stage, we investigated the existence of long-run or cointegrating relationships. We evaluated cointegration using Pedroni's test implemented in *pco* package in *R*. At the fourth stage, based on positive evidence of the long-run relationship of our panel-series, we calculated the dynamic ordinary least squares (DOLS) estimators, as implemented in *cointReg* package in *R*. Figure 1 graphically presents the complete methodological framework, which fits with the approach of recent publications in the field of economics, finance, and energy (*e.g.* Petrović & Lobanov, 2022; Espoir & Ngepah, 2021).

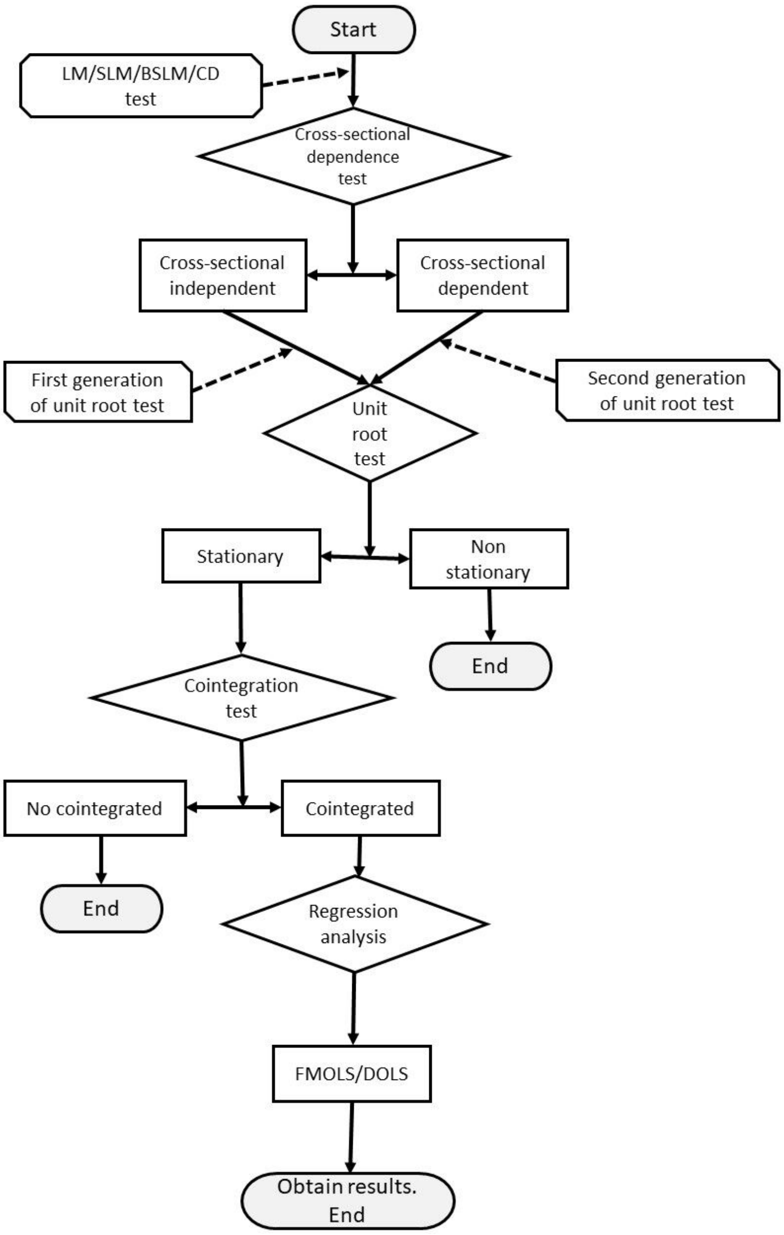

Figure 1. Methodological framework
Source: own elaboration.

Cross-sectional Dependence Test

We started the analysis by evaluating the presence of cross-sectional dependence across countries, that is, the possible dependence of ε_{it} across i's. The source of cross-sectional dependence can either be the relative position of the countries (spatial dependence), where neighbouring countries may be more strongly related than far away ones, or it is based on common factors – whether observable or not– that affect the countries irrespective of their relative position (Croissant & Millo, 2019). Ignoring cross-sectional dependence can lead to several consequences, which encompass inefficient and inconsistent parameter estimates and heteroskedasticity, all of which collectively compromise the validity of hypothesis-testing inferences. Cross-sectional dependence can be evaluated using the null hypothesis H_0: $\rho_{ij} = cor(\varepsilon_{it}, \varepsilon_{jt}) = 0$ for $i \neq j$, where ρ_{ij} is the ij-th estimated sample cross-correlation coefficient defined as

$$\hat{\rho}_{ij} = \hat{\rho}_{ji} = \frac{\sum_{t=1}^{T} \hat{\varepsilon}_{it}\hat{\varepsilon}_{jt}}{\sqrt{\sum_{t=1}^{T} \hat{\varepsilon}_{it}^2}\sqrt{\sum_{t=1}^{T} \hat{\varepsilon}_{jt}^2}} \tag{2}$$

for each pair of countries (i, j), $i \neq j$

$\hat{\varepsilon}_{it}$ being the ordinary least squares (OLS) residual estimated for each country i using T sample observations.

We considered the four different test statistics mentioned earlier for evaluating H_0, whose mathematical expressions and distributions under H_0 are available upon request.

The cross-sectional dependence tests within each panel series (details available upon request) strongly confirm the presence of cross-sectional dependence among countries. Accordingly, we followed the logic of Figure 1 and applied the second generation of the unit root tests as described in the following subsection.

Panel Unit Root Test

This step explores the presence of unit roots considering the cross-sectional dependence present in the panel series. We explored the existence of unit roots using the CIPS test (Im *et al.*, 2003; Pesaran, 2007), in which the null hypothesis was H_0 = the panel-series contains a unit root and is non-stationary. In general, panel series are expected to be stationary at the level I(0) or first difference I(1), thus entailing the rejection of H_0. The presence of unit roots can lead to estimation problems, giving rise to issues such as spurious regressions and endogeneity concerns.

Table 3 reveals that our panel series were non-stationary at their levels. However, they became stationary in their first differences under the model with a constant. Our panel series were integrated of order one, therefore, we proceed with the following stage of cointegration.

Table 3. Panel unit root test results

Variables	Constant	
Panel-series	Level	First difference
MARKET_PERF	-0.57(0.2)	-2.44(0.06)*
SUSTAIN_PERF	-1.73(0.2)	-3.60(0.00)***
TECH_ADOP	-1.51(0.2)	-3.19(0.00)***
OUTPUT_GAP	-1.98(0.2)	-3.153(0.06)*

Note(s): *p <0.01; **p <0.05; ***p < 0.001. We indicated cases when the p-value was greater than 0.1 or smaller than 0.001 as 0.2 and 0.00, respectively.
Source: own study in *R*.

Panel Cointegration Test

The next step was to investigate the presence of a long-run relationship between the dependent variable and the panel series. In econometrics, scholars commonly refer to this phenomenon as cointegration. Cointegration implies a long-term relationship between variables, enabling the estimation of valid long-term parameters and providing meaningful interpretations of relationships. Conversely, employing non-cointegrated variables can give rise to the occurrence of spurious regression. We employed Pedroni's cointegration test, as previously conducted by other studies (*e.g.* Espoir & Ngepah, 2021), to test the null hypothesis of no cointegration (Pedroni, 1999).

Pedroni's test uses seven types of statistics grouped into two categories: panel (or within-dimension-based) statistics and group mean (or between-dimension-based) statistics. The decision to reject H_0 is taken based on the significance of most of the statistics. Under the alternative hypothesis (H_1), the panel variance statistic (denoted in Table 4 as panel-*υ* statistic) diverges to positive infinity. Consequently, we used the right tail of the normal distribution to reject H_0. For each of the other six test statistics, we used the left tail of the normal distribution with large negative values to reject H_0. Table 4. Presents the results of the seven test statistics, integrated with the applied regression models from Table 5. Based on these results, we concluded that our panel series are cointegrated, indicating the existence of a long-run relationship.

Table 4. Panel cointegration test results

Statistic	Model 1-4	Model 5-8
Within-dimension		
panel *υ*-statistic	63.91(0.0)***	0.52(0.3015)
panel *ρ*-statistic	-14.53(0.0)***	-7.49(0.0)***
panel *t*-statistic (non-parametric)	-4.16(0.0)***	-2.06(0.0197)***
panel *t*-statistic (parametric)	-2.42(0.0078)***	-113.32(0.0)***
Between-dimension		
group *ρ*-statistic	-14.03(0.0)***	-8.88(0.0)***
group *t*-statistic (non-parametric)	-3.89(0.0)***	-2.66(0.0039)***
group *t*-statistic (parametric)	-3.38(0.0)***	-2.81(0.0025)***

Note(s): *p <0.01; **p <0.05; ***p < 0.001.
Source: own study in *R*.

Long-run Relationships via DOLS Estimation

After establishing the cointegration relationships, we could estimate the long-run parameters using various econometric techniques, including ordinary least squares, dynamic ordinary least squares (DOLS), or fully modified least squares (FMOLS) estimators. Kao and Chiang (2001) demonstrated the superiority of DOLS over other estimators for estimating cointegrated panel regressions, justifying its adoption in this study.

Table 5 reports the positive and highly significant (at the 1% level) long-run estimates of TA in SMEs on their country-level market performance in Models 1-4. These findings lend support to H1. Based on the estimate from Model 1, a 1% increase in TA is associated with an approximate 4.578% increase in market performance.

For H3a, there was a mixed support. The results indicate that the impact of TA by the SME population on market performance varies across the regional contexts under examination. It exhibits a negative and statistically significant effect in the Baltic countries, while in Central European countries, the effect is positive and statistically significant. Specifically, the elasticity of market performance with respect to TA in Central European (Baltic) countries was 2.377 (-2.004), meaning that a 1% increase in the measure of TA resulted in 2.377% (2.004%) increase (decrease) in their market performance.

Interestingly, the control variable OUTPUT_GAP appears to be significant only in Model 4 , as exemplified by the positive sign and its 5% significance level. This result indicates that a 1% increase in the GDP per capita lag behind the GDP of Germany increases market performance by 0.0001% which is fairly negligible.

Models 5-8 report the long-run estimates of TA in the SMEs on their sustainability performance. The variable of TA is again highly significant at a 1% level in all models. This indicates that, drawing from the estimate from Model 5, the elasticity of sustainability performance with respect to TA is 0.173, meaning that a 1% increase in TA results in a 0.173% increase in sustainability performance for the European SMEs under study, confirming H2. However, the regional dummies do not reach conventional levels of significance, but their combined covariate captured by NEW_EU_MEMB_D remarkably does. Derived from parameter estimates in Model 6, the elasticity of the interaction variable is calculated to be -0.607. This result implies that a 1% increase in the interaction of TA with the newer EU member states leads to a 0.607% decrease in the sustainability performance of their SMEs in comparison to the old EU members, thus providing empirical support for H3b.

Noteworthy, the coefficient of TA is much larger for market performance compared to sustainability performance (4.578 in Model 1 vs. 0.173 in Model 5) which signals the much larger impact of TA by SMEs towards the traditional performance measure.

One may observe the positive and significant parameter estimate for OUTPUT_GAP for sustainability performance in Models 5, 7, and 8 in Table 5. The estimates of Model 5 indicate that a 1% increase in the GDP per capita lag behind the GDP of Germany increases sustainability performance by 0.00005%, constituting a relatively modest impact.

Table 5. Panel DOLS result

Dependent variable: MARKET_PERF								
Variables	Model 1		Model 2		Model 3		Model 4	
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
TECH_ADOP	4.578***	11.7	4.713***	8.2	4.878***	12.8	4.429***	12.8
TECH_ADOP × NEW_EU_MEMB_D	–		-0.726	-0.3	-		–	
TECH_ADOP × BALTIC_D	–		–		-2.004**	-2.1	–	
TECH_ADOP × CENT_EUR_D	–		–		–		2.377**	2.6
OUTPUT_GAP	0.00004	0.7	-0.00002	-0.09	-0.00003	-0.43	0.0001**	2.0
Optimal number of lags	0		0		5		5	
Optimal number of leads	2		2		4		4	
Kernel for the long-run variance	Barlett kernel		Barlett kernel		Barlett kernel		Barlett kernel	
Bandwidth for the long-run variance	Andrews, 1991		Andrews, 1991		Andrews, 1991		Andrews, 1991	
Dependent variable: SUSTAIN_PERF								
Variables	Model 5		Model 6		Model 7		Model 8	
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
TECH_ADOP	0.173***	2.7	0.286***	3.8	0.1905***	3.1	0.171***	2.7
TECH_ADOP × NEW_EU_MEMB_D	–		-0.607**	-2.1	–		–	
TECH_ADOP × BALTIC_D	–		–		-0.139	-1.02	–	
TECH_ADOP × CENT_EUR_D	–		–		-		0.037	0.2
OUTPUT_GAP	0.00005***	5.4	0.0000004	0.01	0.00004***	4.2	0.00005***	4.5
Optimal number of lags	0		0		0		0	
Optimal number of leads	0		0		0		0	
Kernel for the long-run variance	Barlett kernel		Barlett kernel		Barlett kernel		Barlett kernel	
Bandwidth for the long-run variance	Andrews, 1991		Andrews, 1991		Andrews, 1991		Andrews, 1991	

Note(s): *p <0.01; **p <0.05; ***p < 0.001. Optimal number of lags and leads based on the AIC.
Source: own study in *R*.

CONCLUSIONS

Study Contributions

The primary objective of this article is to contribute to the literature, which predominantly focuses on the effects of TA at the company or industry level, by examining the impact of TA by SMEs within the broader context of SMEs at the national level. Moreover, we aimed to shed light on whether the TA-performance link is contingent upon the innovation potential of the region where a country's SMEs are situated.

Our results unveiled a positive relationship between TA and market performance at the country level. However, long-run equilibrium relationships also demonstrate that these effects differ among the new EU member countries, resulting in a positive effect for Central European countries and a negative effect for Baltic countries. Noteworthy, both Central European and Baltic countries are considered innovation-laggard regions compared to the sampled Western European countries. This disparity can partly be attributed to differences in industry structures. The Baltic countries demonstrate a higher proportion of high-tech ICT industries, whereas the Central European economies, particularly within their SMEs, tend to be more oriented towards traditional manufacturing industries.

Furthermore, our study confirmed the positive impact of TA on sustainability performance within European SMEs at the country level. However, this effect appears to be detrimental to a specific group of countries, namely the new member countries comprised of Baltic and Central European states, when compared to the older EU member states. One plausible explanation for this disparity could be the relatively weaker ESG mentality among practising managers in the SMEs within this group of countries, which may hinder their ability to harness TA effectively for the improvement of their firm's sustainability performance.

Furthermore, our findings underscore a noteworthy trend: TA has a significantly greater impact on market performance than sustainability performance. This observation calls for a substantial shift in both governmental and corporate policies that encourages and supports deeper commitment by SMEs to technology-driven green transition initiatives.

Implications for Policymakers

Several implications emerge from the results. The study highlights the positive impact of TA on sustainability performance, underlining the importance of ESG principles for combating polluting industries and political allies (consider the case of the US – Lippman, 2023). Hence, TA within SMEs can play a pivotal role in mitigating populist arguments against green economic transitions. Nevertheless, governments incentivise to SMEs and establish a favourable regulatory environment to facilitate the adoption of environmentally friendly technologies (Khalilov & Yi, 2021).

We also found that the SMEs of newer EU member countries tend to follow a rigid pathway when adopting technologies to benefit from the green transition. Therefore, the EU should focus more on direct policies tailored to the development of SMEs. The innovation management literature neatly documents the existence of a sophisticated network of R&D centres or science parks in Western Europe (the Netherlands – Duc & Lindeque, 2018; Sweden – Löfsten & Lindelöf, 2005; Belgium – Spithoven *et al.*, 2011) that directly help local SMEs to co-develop advanced technologies for for-profit reasons. Such a dedicated initiative backed by EU funding programs would be valuable for the newer Member States. This approach would definitely increase the effectiveness of REPowerEU policy (Bernat *et al.,* 2023) by involving the SME sector more in developing and adopting green technologies that foster the transition to a carbon-free economic structure. As we also identified the relative inability of the Baltic states to turn TA into positive market performance, establishing a well-oiled network of R&D centres could assist in this regard.

Implications for Managers and Practitioners

Researchers interested in elaborating more precise steps tailored around our framework might explore how specific technology access strategies influence technology adoption and their combined impact on performance in the context of SMEs at the country level.

Our results demonstrate that company managers at Baltic firms lag behind their Central and Western European counterparts in turning TA into market success. Aside from the differences in industry structure that favour emerging ICT fields, they may lack complementary assets to ensure the profitable market applications of their technologies. Among other solutions, managers attempt to create patents and trademarks as integral elements of a technology management strategy, thereby enhancing their market positions (Fosfuri *et al.*, 2008). Results also show that the SMEs of the Baltic and Central European states, compared to those of Western Europeans, are laggards in terms of using TA to achieve robust sustainability performance. Managers can improve attentional engagement in firms and the development of technologies with positive environmental impact, focusing on problem-solving, sensemaking, and decision-making (Ocasio, 2011). Moreover, SME managers in new Member States should focus on open innovation (Colombo *et al*., 2014), licensing strategies (Smallbone *et al.*, 2022), and dynamic capabilities to enhance their adaptability, performance, and evolutionary fit (Teece, 2007). These tools may help SMEs access lacking innovation inputs, combat organisational myopia, enhance their technology and product market strategies, and adapt to changing market conditions (van de Vrande *et al*., 2009; Levinthal & March, 1993; Weaven *et al*., 2021).

Limitations and Future Research

The research has some shortcomings that represent an opportunity for further study. The collected data are secondary data that come from different databases. Data collection and aggregation procedures varied among countries. However, Eurostat, OECD or the Global Entrepreneurship Monitor supervised them through quality control processes. The results of the present study indicate that a newly designed and exhaustive survey with a set of complementary items, like the one used for the community innovation survey should be issued to European SMEs in the future to boost representativity and comparison. The use of causality tests is advisable to gain further insights into the relationships of panel series.

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