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Commonalities of standards certification and research and development as enablers of firms' sustainable innovation and technological progress

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ABSTRACT

Adoption of international standards and investment in research and development (R&D), can be seen as two possible paths to support enterprises' sustainable innovation and technological progress. This study argues that some aspects of R&D investment and certification to international standards are connected by identifying common factors that influence standards certification and business investment in R&D and examining the potential associations between the two. First, we examine the relationship between standards certification and R&D investments in European firms and identify enterprise characteristics that potentially affect each of the two concerns, focusing on differences and similarities. The analysis uses data from the World Bank Enterprise Surveys collected in 2018 and 2019 in selected European countries. We analyse the share and characteristics of firms that applied international standards and R&D expenditures. The probit regression results reveal a positive correlation between R&D expenditures and certification. Other factors affecting the probability of certification include size, export focus and industry. Bivariate probit regression allows us to identify common factors affecting both R&D expenditures and certification, showing significant variations between different forms of entrepreneurship. Subsidiaries of larger companies have a greater chance of being certified and investing in R&D. In contrast, sole proprietorships are significantly less active in both cases. Mentioned factors affects firms' capabilities to develop sustainable innovation and adopt new sustainable technologies.

Introduction

Research and development (R&D) activities are widely recognised as a key prerequisite for advancing innovation in the business sector (Baumann & Kritikos, 2016; Guo et al., 2016). Motivated by the concept of sustainable development, entrepreneurs are increasingly expected to develop sustainable innovation, e.g. innovations that are aligned with selected economic, environmental and social goals. Firms invest in R&D to strengthen knowledge and innovation capabilities (Lee & Suh, 2022). R&D investment has a crucial role in firms' adoption of new sustainable technology and development of high-tech products (Sandu & Ciocanel, 2014). The intention to bring new innovative goods or services to the market often requires state-of-the-art technologies, which are primarily the result of R&D. Sustainable innovation is closely related to firms' environmental performance, which is further affected by business R&D expenditures. R&D investment improves firm's environmental performance as measured by energy and carbon emissions intensity (Alam et al., 2019) and eco-efficiency. R&D has also been found to be a key accelerator of sustainable innovation (Sarpong et al., 2023). Safitri et al.

(2020) demonstrated that R&D investment is an essential factor in improving eco-efficiency, while environmental investment exhibits no correlation with firms' eco-efficiency. Furthermore, R&D investment is essential for determining optimal e-waste processing technology (Roy et al., 2022) and ensuring environmental sustainability, reducing carbon emissions and lowering ecological footprint (Adedoyin et al., 2020; Fernández et al., 2018). R&D activities can be performed in-house using firms' existing research capacities or by acquiring capabilities from external research institutions. In both cases, firms need to invest financial resources to obtain knowledge or technology that is important for innovation. Business R&D expenditure not only fosters sustainable innovation and technological progress but also enhances firms' competitiveness and has been linked to increasing firms' growth (Pieri et al., 2018), profitability (Freihat & Kanakriyah, 2017) and labour productivity (Hunady et al., 2020).

Another action that can affect enterprises' sustainable innovation and economic performance is acquiring certification based on accepted international standards. The certification process also requires significant investment; however, firms can gain additional benefits from

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international standardisation. The adoption of standards is often considered a driver of innovation (Swann & Lambert, 2017). One way that standards can act as catalysts for innovation is by reducing the time required to develop market inventions and innovative technologies. The standardisation process also levels the playing field, which promotes further competition and innovation. Standards also increase trust in innovative products and facilitate their diffusion (Blind, 2009). López-Mielgo et al. (2009) found a positive relationship between standardisation, quality control and firms' innovation capabilities. Several practical examples of how adopting standards led to sustainable innovation and technological development in entrepreneurship can be cited. Certification and technical standards encourage the adoption of new sustainable energy products, particularly in ensuring quality and sustainability (Koyunoglu, 2024). Internationally recognised environmental standards such as ISO 14,001 appear to facilitate corporate technological innovation (He & Shen, 2019). Furthermore, international standards and certification are closely related to sustainability goals and can also be considered tools of environmental policy. The European Union (EU) environmental policy goals are often regulated within the same standard. The main commitments are aimed at establishing minimum quality and protection standards (Ruiz et al., 2023). Enterprises' implementation of common international standards such as ISO 9001, ISO 14,001, ISO 50,001 and ISO 45,001 introduces lean production systems and improves sustainability (Zenchanka & Malchenka, 2018). According to International Organisation for Standardisation (2024), international standards provide a base for innovation and represent essential tools to help governments, industry and consumers contribute to the achievement of every one of the United Nations Sustainable Development Goals (SDGs). For each goal, the ISO has identified the standards that make the most significant contribution. For example, the ISO 14,000 family of standards related to environmental management systems primarily supports SDG 13, which is dedicated to climate action. ISO 56,002 establishes a base for meeting SDG 9, Industry, Innovation and Infrastructure. The most widespread standard, ISO 9001, covers the largest number of UN SDGs, including SDG 1, SDG 9, SDG 12 and SDG 14 (Georguiev & Kostadinova, 2021). Hence, R&D expenditures and international standards certifications have the potential to improve sustainability, sustainable innovation and technological development. Moreover, international standards certification also acting as a signal of quality for consumers, reducing the transaction cost and increasing sales (Swann et al., 1996). Hence, due to limited financial resources, firms can consider R&D investment and international certification as two alternatives to reach similar goals. In this case, both types of investment activities appear to function as substitutes, and introduced standards can often lead to an increase in R&D expenditures. For example, in the case of environmental standards that demand certain eco-innovations. The same positive effect is also possible in the opposite direction. Innovative products, services and processes produced through R&D efforts can also compel the need for certification. Therefore, the potential relationship between these two approaches is debatable. Our study examines this potential relationship and the factors that affect them to investigate the association using micro-level data. Moreover, the study also focused on identifying of factors that affect the probability of certification and R&D investment at the firm level. The results offer new insights into decision-making processes related to these tools for supporting sustainable innovation and technological progress in entrepreneurship.

To the best of our knowledge, an extremely limited number of studies have examined factors affecting certification and R&D business expenditures in Europe. Moreover, no other study has directly examined this relationship using micro-level data from European firms. Although several previous studies have demonstrated a positive effect of R&D on innovation (Alvarez, 2016; Mairess & Mohnen, 2004), it remains unclear whether this could be further transformed to a higher level of certification in firms, and the evidence thus far has been extremely limited and contradictory. Some of the rare studies have found a positive effect of R&D on specific types of certificates in Asia (Nakamura et al.,

2001; Wu et al., 2007). In contrast, many doubts have been raised concerning this effect (e.g. Gray & Shadbegian, 1998). This study further examines this unsettled issue based on empirical evidence. We also identify the common factors of international certification and R&D investment, presenting a novel perspective, revealing relevant new results. The majority of the previous research has focused on the characteristics or factors affecting certification alone, only using data from a relatively small number of selected EU countries or member countries of the Organisation for Economic Development and Co-operation. This research uses micro-data provided by the World Bank Enterprise Surveys (WBES) (2022) conducted in selected European countries in 2018 and 2019. This is an extensive source of micro-data with more than 15,287 available observations that allows us to achieve relevant and robust results. From a methodological perspective, we also employ an original concept of combining probit and bivariate probit regression models, which allows us to identify factors affecting both phenomena, some of which are found to be common for both. Firms being subsidiaries of a larger company is found to be a significant factor affecting the probability of R&D investment and certification. Furthermore, enterprises' location in a capital or main city of a country appears to be significant for R&D investment but not for certification to international standards.

The remainder of this paper is organised as follows. In the next section, we provide a concise literature review of previous studies that have focused on certification and business R&D expenditures as two tools supporting enterprises' sustainable innovation and adoption of sustainable technology. This section also focuses on the potential relationship between both problems. Section 3 describes the data and methodology used in our research. In section 4, we detail and discuss the most important results achieved in the analysis. Finally, section 5 presents a conclusion including several economic implications.

Literature review

A standard is a documented agreement that contains guidelines to ensure that materials, products, processes, representations or services are suitable for their purpose (Allen & Sriram, 2000). Following this definition, standardisation is a process of establishing, adapting and conforming to a specified standard. Standard implementation processes can significantly vary in different circumstances (Hawkins et al., 2017). One of the main goals of certification is allowing enterprises to eliminate quality control checks on suppliers (Tirole, 1988). In particular, internationally recognised standards may help reduce information costs and subsequently increase sales (Swann et al., 1996). According to Hudson and Orviska (2013), the ISO 9000 family can successfully function as a quality signal in a world of asymmetric information. Certification can also be defined as legal recognition that a certain product or system complies with specified standards (de la Vara et al., 2019). A certificate is awarded when products or production processes comply with the defined standards. Factors such as firms' characteristics seem to have a significant influence on the probability of certification to international standards across sectors (Pekovic, 2010). The scope of certification and the number of standards in which a firm is certified appear to be influenced by firms' size, primary export markets, awareness of trade standards and market diversification (Masakure et al., 2011). Moreover, firms in countries with lower quality institutions benefit more from quality certification (Ullah, 2022). While only very limited evidence has been produced concerning the relationship between certification and firms' R&D, significant attention has been devoted to the relationship between standards and innovation, which has been an important issue for several years. Research has shown that standards can support innovation (Shin et al., 2015; Swann & Lambert, 2017). For instance, as noted previously, López-Mielgo et al. (2009) revealed a positive relationship between innovation, standardisation and quality control. Enterprises' introduction of quality control management has been linked to increased innovation (Tang, 1998). Moreover, certification appears to have a positive effect on sustainable innovation (He & Shen, 2019;

Koyunoglu, 2024) and overall entrepreneurship sustainability (Zenchanka & Malchenka, 2018). The adoption of widely accepted standards such as ISO 9000 and ISO 14,000 improves firms' awareness and balance of sustainability priorities in entrepreneurship (Pawliczek & Piszczur, 2013). Conversely, some evidence has indicated that standards can hinder creativity and innovation in entrepreneurship (Dick, 2000), which can be attributed to increased bureaucracy and implementation of unnecessarily formal rules that are often associated with standardisation.

In contrast to the vivid discussion on standards and innovation, significantly less research attention is paid to the potential nexus between certification to international standards and investment in R&D. R&D expenditures are theoretically considered to be the first step in developing fundamental innovation capabilities. Several studies have empirically shown a positive effect of R&D on innovation performance (Alvarez, 2016; Mairess & Mohnen, 2004; Savrul & Incekara., 2015). The positive effect of R&D on innovation can also be demonstrated by growth in patenting as a proxy of innovation activity (Gallié & Legros, 2012). Enterprises' investment in R&D specifically supports sustainable innovation (Sarpong et al., 2023) and the adoption of new sustainable technology (Alam et al., 2019; Sandu & Ciocanel, 2014).

Patenting and standardisation are processes for defining and codifying technology. While patents describe and codify novel inventions to temporarily exclude others from using them, in contrast, standards define commonly accepted and used products, services and processes (Baron & Pohlmann, 2018). Despite different aims, standards and patents interact: R&D activities lead to patent development, which can compel standardisation by standard-setting organisations (SSOs). This link is bidirectional as inventors respond to the objectives set by SSOs and SSOs redefine standards based on new technologies (Baron & Pohlmann, 2018). This represents one of the possible interactions between R&D and standardisation. Utterback (1994) argued that as technologies develop and advance, standards are crucial for ensuring the performance, conformity and safety of innovative products and processes. Moreover, standards have an important influence on new technology adoption and expanding the scope of application (Blind, 2016; Hawkins et al., 2017). Several previous studies empirically examined company-level data, revealing a positive relationship between R&D intensity and involvement in standardisation (Blind & Mangelsdorf, 2012; Wakke et al., 2015), which may be due to the signalling effect of standards. As argued by Terlaak and King (2006), the signalling effect of ISO 9000 certification may be more significant for companies with high R&D and advertising expenditures. Wang et al. (2014) found that the positive effects of R&D investments on company performance depend on quality management and the extent to which a firm exceeds the minimum requirements for ISO 9000 certification in particular. The relationship between R&D and standards can differ based on the type of standard referenced. Perhaps the most evident connection appears to be in the case of environmental standards. A significant share of companies that endeavour to adopt this type of standard must invest in R&D and adopt new environmentally innovative solutions. Innovation specific to technologies that reduce environmental externalities from production processes have been found to correspond well with the goal of ISO 14,001. Wu et al. (2007) demonstrated that R&D expenditure positively affects decisions on ISO 14,001 certification. The authors found that Taiwanese firms with more intangible assets (such as R&D) are more likely to seek ISO 14,001 certification. Nakamura et al. (2001) found a similar correlation but assumed that the effect was primarily in the opposite direction. These results indicated firms with high R&D investment found it easier to implement the ISO standard. This can be credited to more frequent development of new technological solutions for environmental challenges. In addition to the adoption of ISO 14,001 certificates, retaining these certificates can be essential for generating environmental innovations. Inoue et al. (2013) revealed that the duration of firms' holding an ISO 14,001 certificate is positively related to the amount of environmental R&D expenditure. This finding again supports

the existence of a relationship between certification and sustainable innovation generated by environmental R&D.

In contrast to the results above, several studies have refuted this relationship. Most importantly, findings have shown that firms do not always independently undertake the innovation process, instead implementing R&D outsourcing. Especially in some industries, i.e. pharmaceuticals, most R&D is undertaken outside of firms (Dushnitsky & Lenox, 2005). Even in firms where internal R&D is the main driver of innovation, external R&D can be used as an additional resource (Singh & Smith, 2004). Moreover, high compliance costs related to certification may reduce enterprises' ability to perform R&D (Gray & Shadbegian, 1998), which can lead to technological lock-in (Comin and Hobijn (2009). Investment in R&D can also represent an alternative to international certification. ISO 9001 could help service-oriented firms to formalise the innovation process and improve internal innovation activities (Mangiarotti & Riillo, 2014). Nevertheless, the effect of both on innovation can differ depending on the type of innovation. Benner and Tushman (2002) argued that ISO 9001 quality certification has a positive effect on incremental innovation but a negative effect on more radical innovation. In contrast, Mangiarotti and Riillo (2014) concluded that ISO 9001 certification supports manufacturing firms' technological innovation and service firms' non-technological innovation. In particular, radical types of innovation can be closely linked to R&D activities. Contrary to other studies, Sam and Song (2022) found that non-certified firms exhibit twice as high R&D intensity compared with firms holding ISO 14,001 certification.

Material and methods

This study endeavours to identify the factors that affect international standards certification and R&D. In our case, such factors represent firms' characteristics, which could have an impact on decisions concerning certification and the allocation of R&D expenditure. To achieve these aims, our analysis is based on the available data from the WBES database (World Bank, 2022). The dataset includes firm-level data based on a survey of a representative sample of economies' private sector, excluding the agricultural sector that were conducted in different geographic regions and cover companies of different sizes. The surveys are an on-going World Bank project to collect objective data based on firms' experiences and perceptions of the environments in which they operate. Data from the survey are primarily used by the World Bank and other institutions to benchmark indicators that represent the quality of the business and investment environment. As of December 2019, the survey covers over 180,000 firms in 150 countries, of which 142 have been surveyed following a standard methodology, allowing for comparisons across countries and time. Despite the worldwide representation of countries in the survey, this study only references data for select European countries. Limited studies have focused on the factors that affect certification and R&D expenditures in Europe. Countries are selected based on data availability; hence, all European countries with available micro-data from the questionnaire survey conducted in 2018 and 2019 are included in our sample, the majority of which were conducted in 2019. Table 1 presents the full list of the countries included in our analysis, and the number of enterprises captured for each country. The same European countries used in our research (plus a few Asian countries) were also examined by Ullah (2022). This study explores the relationship between small and medium-sized enterprise (SME) innovation and international standards certification. We decided to solely focus on European firms with slightly more similar economic conditions, including 17 EU member states and 9 non-EU European countries.

The dataset includes 15,287 complete observations for the period under study; however, missing observations for some variables used in the analysis limited the number of observations to 14,216. The study's primary sampling unit represents the establishment, which is defined as the physical location where business is conducted and where industrial operations occur or services are provided. A firm may include one or

Table 1
Description of the cross-sectional dataset used in the analysis.

Country	No. of complete observations	Country	No. of complete observations
Albania	377	Lithuania	358
Belarus	600	Luxembourg	170
Belgium	614	Moldova	360
Bosnia and Herzegovina	362	Montenegro	150
Bulgaria	772	North Macedonia	360
Croatia	404	Poland	1369
Cyprus	240	Portugal	1062
Czechia	502	Romania	814
Estonia	360	Russia	1323
Greece	600	Serbia	361
Hungary	805	Slovakia	429
Italy	780	Slovenia	409
Latvia	369	Ukraine	1337

Source: Authors' calculations based on the WBES (2022).

more establishments, but each establishment must make its own financial decisions and have its own management and separate financial statements. The sample for all countries was selected using stratified random sampling. The World Bank implements the survey using a two-stage procedure in which the first step includes a first screener questionnaire over the phone to determine eligibility and make appointments. The second step is an in-person interview with the manager, owner or director of the establishment. These interviews were mostly conducted via online personal interviewing. We focus our attention on several questions in the survey related to certification, R&D and other key establishment characteristics.

We employ two main dependent variables, the first of which indicates establishments' international standards certification. Firms were asked whether the establishment received an internationally recognised certification. If certification was acknowledged, the answer was coded as one, and if not, it was coded as zero. Observations with ambiguous answers were excluded from the sample. The second dependent variable includes answers to the question of whether the company invested in R&D, which was again coded as one or zero based on the answer. Hence, the variable only captures the fact that the company had any R&D expenditures but does not consider the scope. This variable is also used as the dependent variable in the first model. Table 2 summarises and describes all dependent and independent variables used in our models.

The study employs probit regression to examine the factors related to the increased or decreased probability of certification and innovation expenditure. Hence, the first regression uses certification as the dependent variable, and other variables characterising the establishment, industry and country are independent variables that are potential factors affecting standards certification. We focus on variables capturing R&D expenditures. The selection of dependent variables is determined by data availability; however, we contend that the variables used are the most relevant characteristics related to economic, financial, managerial and organisational factors. We include establishments' size and sector and legal status. Furthermore, additional variables are employed to capture potential foreign ownership, managers' gender and experience and location. We also consider the share of domestic sales, direct exports and the use of foreign licences.

The second set of regressions is estimated using individual probit and bivariate probit approaches. In bivariate probit, the dependent variables (R&D expenditure and standards certification) are combined in a single model simultaneously, while the set of independent variables is identical. The bivariate probit allows us to examine the correlations between the dependent variables. We use probit and logistic regressions to test the robustness of our results. Since these models have similar characteristics and the results were slightly better for probit (especially pseudo-R-squared (R^2)), we continue to use only the probit model since both

Table 2
Description of the variables used in the analysis.

Variable	Description/Question	Coding and/or unit of measurement
Certification	Does the establishment have an internationally recognised quality certification?	Yes = 1; No = 0.
R&D expenditures	Establishment spending on R&D in the last fiscal year (excluding market research).	Yes = 1; No = 0.
Size	Size of the firm based on number of employees. Three categories: small (<20), medium (20–99), large (100 and over).	Small = 1; Medium = 2; Large = 3.
Part of a large firm	Establishment is a part of a large firm.	Yes = 1; No = 0.
Capital or main business city	Establishment in a capital or main business city in the country.	Yes = 1; No = 0.
Foreign ownership	More than 50 % owned by private foreign individuals, companies or organisations.	Yes = 1; No = 0.
Sole proprietor	Legal status of the establishment is sole proprietorship.	Yes = 1; No = 0.
Publicly traded comp.	Legal status of the establishment is shareholding company with shares traded in the stock market.	Yes = 1; No = 0.
Female top manager	Is the top manager female?	Yes = 1; No = 0.
Having a website	Establishment has its own website.	Yes = 1; No = 0.
Managers' experience	How many years of experience working in this sector does the top manager have?	Number of years.
Share of direct export	Share of direct export sales.	%
Share of national sales	Share of national sales.	%
Foreign licence	Do you use technology licensed from a foreign-owned company?	Yes = 1; No = 0.
Industry dummy variables	Industries/sectors used as individual dummy variables.	
Country dummy variables	Twenty-five of 26 countries used as individual dummy variables.	

Source: Authors' calculations based on the WBES (2022).

models essentially produced the same results.

In line with our main aims, we present three research hypotheses, all of which are developed referencing the results of previous studies (Blind & Mangelsdorf, 2012; Inoue et al., 2013; Mangiarotti & Riillo, 2014; Wakke et al., 2015) and theoretical assumptions. As noted, an on-going debate has occurred in the economic literature concerning the potential relationship between R&D expenditures and international standards certification. However, most of the previous studies have found a positive correlation or effect between these indicators. Most arguments have been in favour of the potential positive effect of R&D expenditures on standards certification. Hence, we present the following research hypotheses:

H01: A positive correlation/association exists between international standards certification and R&D business expenditures.

Because these concerns are often related, both approaches likely share similar influencing factors. Establishments' characteristics such as size, ownership or export focus can be related to both; hence, we also assume the following:

H02: Most factors related to firms' characteristics have similar effects on decisions concerning R&D investments and international standards certification.

Despite several similarities between the two approaches examined, some differences can be evident across industries. As noted in section 2, R&D investments are generally typical for specific sectors with a high share of technological innovation. Furthermore, certification is also typical for some sectors, but it is not strictly connected to certain types of industries. Based on these assumptions, we propose our third research

hypothesis as follows:

H03: The effect of R&D investments and international standards certification differs based on the type of economic sector.

All three research hypotheses are further examined and tested using empirical analysis.

Results and discussion

Our analysis initially focuses on examining standards certification and R&D expenditure in European firms separately. Fig. 1 illustrates the share of enterprises that adopted internationally recognised standards. Among the selected European countries in the dataset, the highest share of certification is in Italy. Firms located in countries like Hungary, Bulgaria and Czechia also reported certification very often. Notably, these are all eastern EU member states. Concerning the type of certificate, more than 70 % of certified respondents indicated that they obtained a certificate from the ISO 9000 family (Fig. 2). ISO 14,000 families were reported by approximately 19 % of respondents. The ISO 9000 family is the most common standard in our sample. ISO 9001 represents 65 % of all ISO certificates awarded in 2021 (International Organization for Standardization, 2024). The ISO 14,000 and ISO 9000 families of standards are associated with sustainable development goals and enterprises’ sustainable innovation.

In the next part of the analysis, we pay attention to expenditure on R&D and its potential relation to certification. Respondents have been asked in the survey whether they had any expenditures on R&D during

the last fiscal year. The results classified based on the countries of the respondents are shown in Fig. 3. The highest shares of those who have any R&D expenditure are identified in Belgium, followed by Slovenia and Luxembourg. On the other end, Lithuania, Poland and Croatia have a very low share of firms with R&D expenditures.

We next focus on the commonalities between standards certification and firms with any R&D expenditures. The type of standard can also have some influence; therefore, we examine the differences among them in Fig. 4.

The types of standards are classified based on certified firms’ reporting requirements, although such reports are not always completely accurate. Firms with Hazard Analysis and Critical Control Points certification appear to be less likely to invest in R&D. In contrast, firms with ISO 140,000 certification and those with other types of standards are most likely to invest in R&D.

If a company is already monitoring processes and performance, management can be a step closer to considering certification. This assumption is confirmed by our data. More than 48 % of the establishments engaged in performance monitoring adopted internationally recognised standards, which is higher than the average (see Table 3). However, a relatively high share of respondents did not share information concerning this issue or refused to answer the related question. The proportion of establishments with certificates was even higher for the group of respondents who reported any R&D expenditures in the fiscal year (58.3 %).

We next conduct probit regression to identify the factors affecting

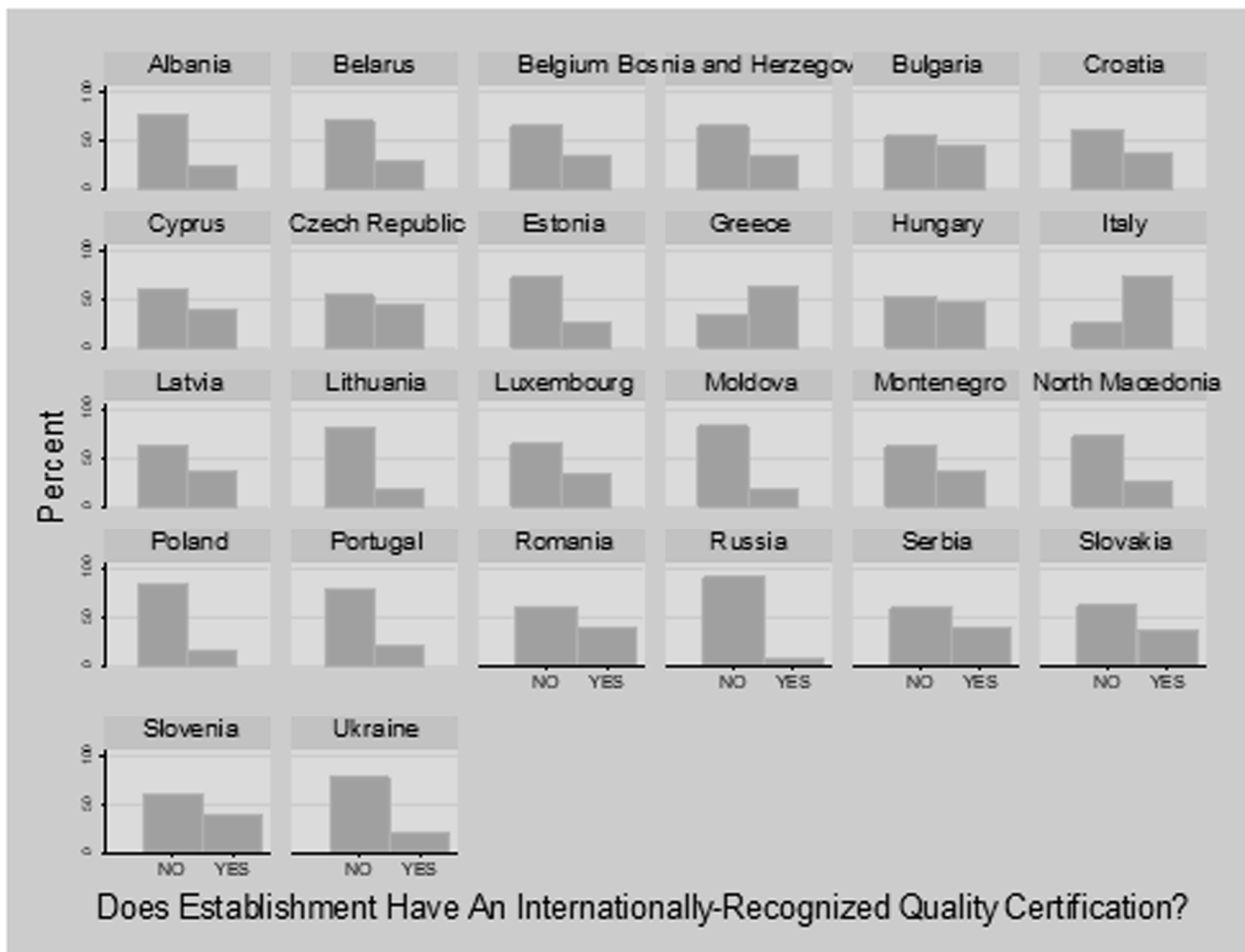


Fig. 1. Proportion of establishments with internationally recognised certificates in selected European countries. Source: Authors’ calculations based on the WBES (2022).

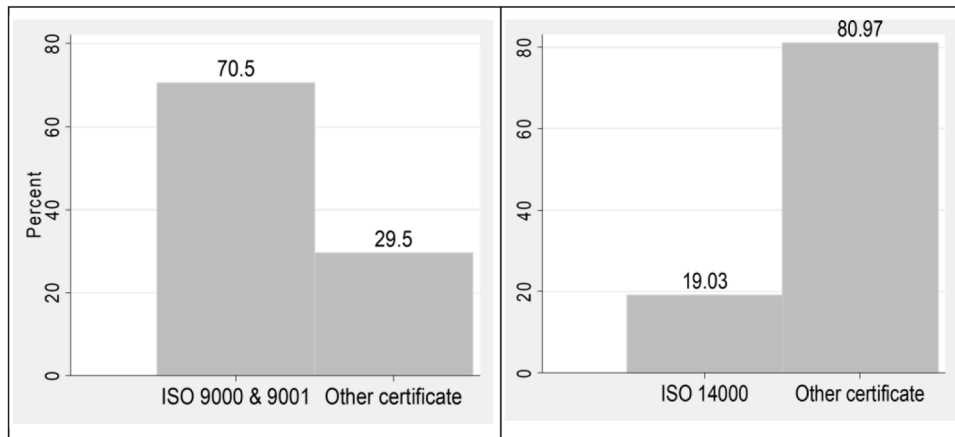


Fig. 2. Proportion of ISO 9000/9001 and ISO 1400 international standards in all reported certifications. Source: Authors' calculations based on the WBES (2022).

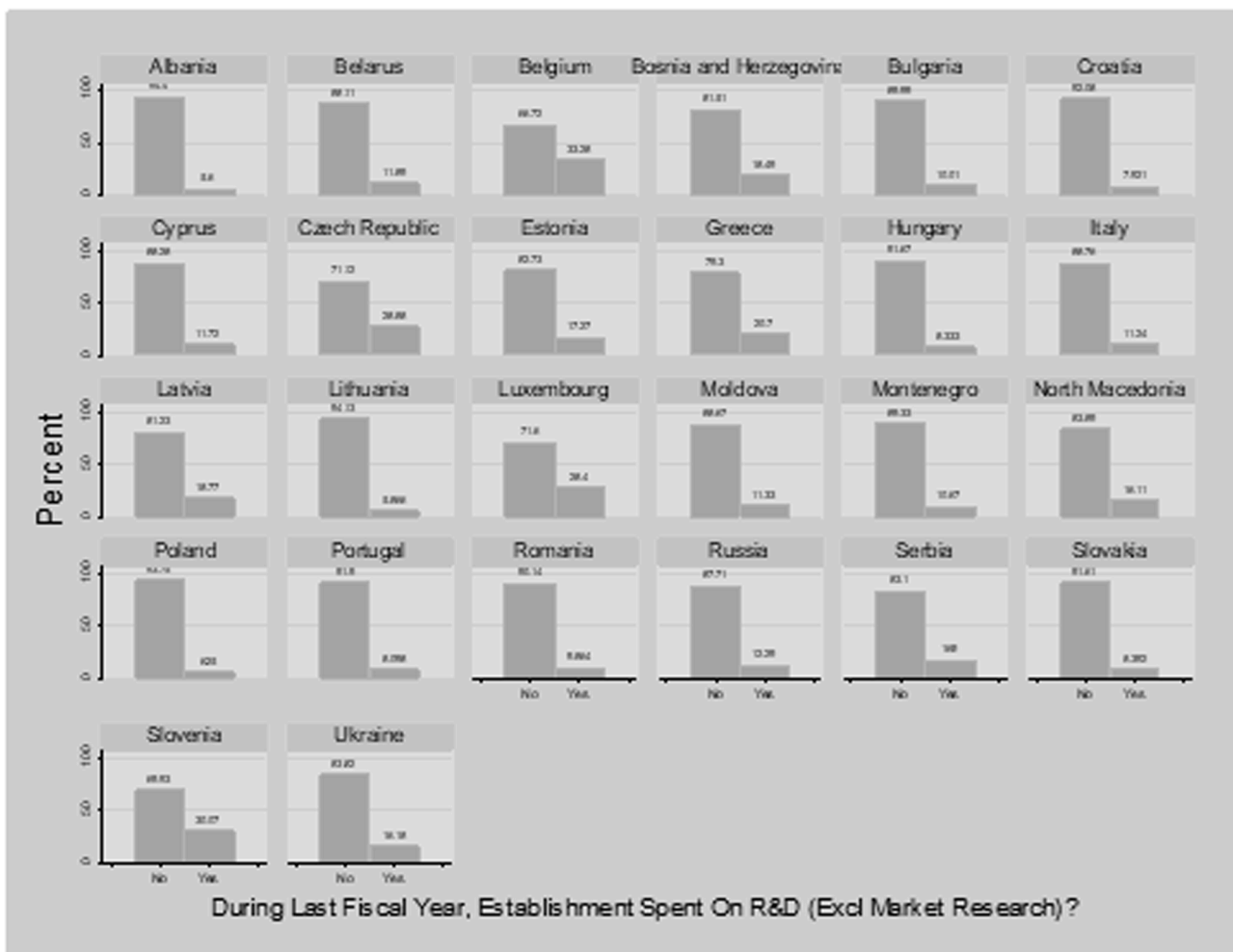


Fig. 3. Proportion of establishments with and without R&D expenditures on R&D in the previous fiscal year in European countries. Source: Authors' calculations based on the WBES (2022).

certification. We are at least capable of capturing characteristics that are significantly correlated with a higher probability of certification. We use all variables concerning firm characteristics introduced in the methodology section as independent variables in the probit regression. We also introduce eight sector and country dummy variables. The dependent variable captures establishments' adoption of internationally recognised

standards. Table 4 presents the results of the regression analysis, revealing several characteristics that can affect the probability of firms' standards certification. From our perspective, the most important finding is related to R&D expenditure, which appears to have a positive and statistically significant effect on certification. Considering potential reverse causality, this effect can be present in both directions; however,

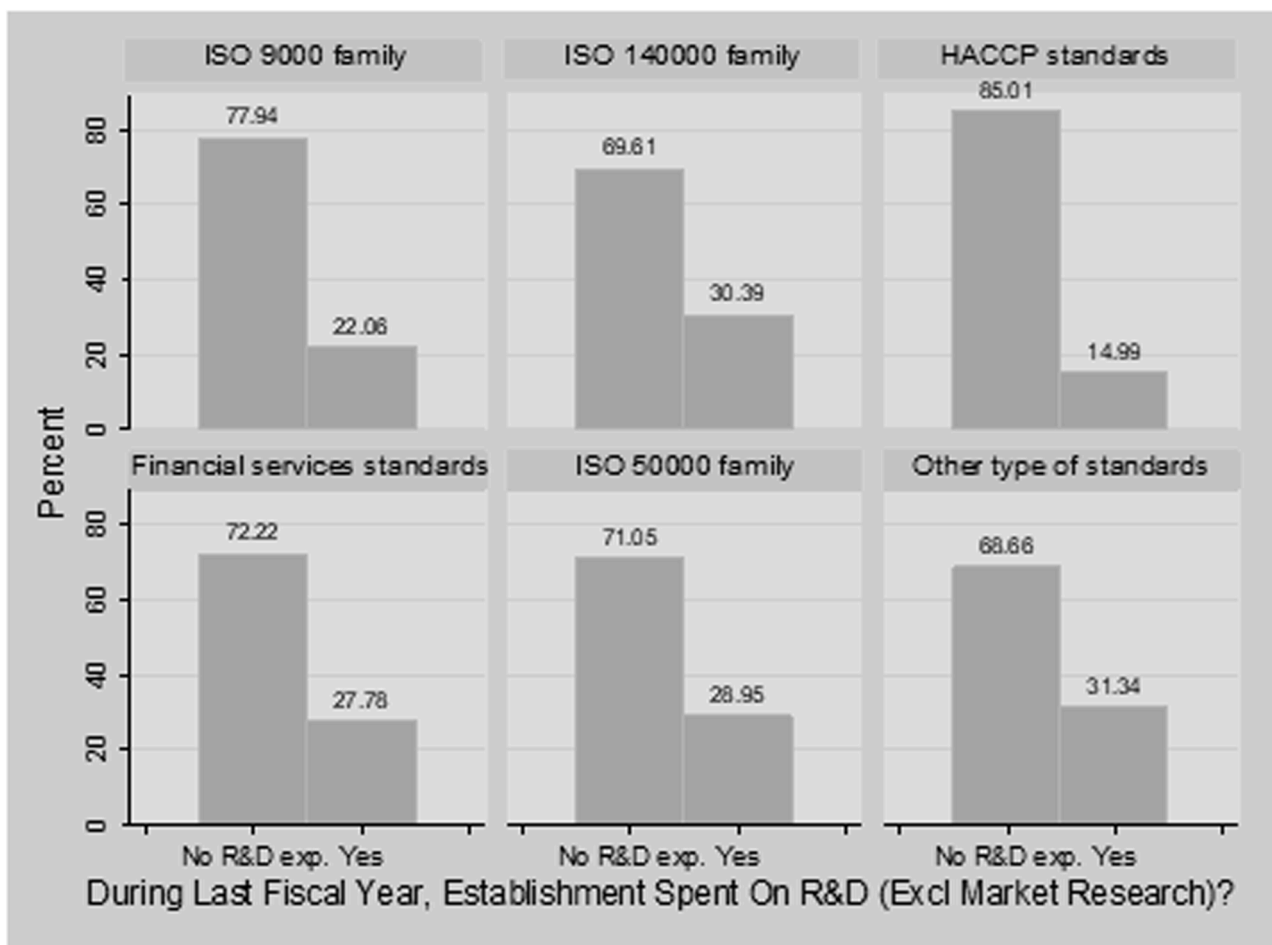


Fig. 4. Proportion of enterprises with and without R&D expenditures classified based the type of standards certification. Source: Authors' calculation based on the WBES (2022).

Table 3 Proportion of enterprises with international standards certification classified based on R&D expenditure and performance monitoring.

Variable	Does your establishment have an internationally recognised certification?		Combined
	YES	NO	
Any R&D expenditures in the fiscal year	YES	1175 (58.31 %)	2015
	NO	840 (41.6 %)	
Monitoring production performance indicators	YES	2983 (48.64 %)	6136
	NO	3153 (51.39 %)	
Combined	4816	10,073	
Any R&D expenditures in the fiscal year	YES	3641 (75.6 %)	12,874
	NO	9233 (91.67 %)	
Monitoring production performance indicators	YES	695 (17.74 %)	2487
	NO	1792 (72.05 %)	
Combined	3708	5000	

Source: Authors' calculations based on the WBES (2022).

we can conclude that the probability of having any R&D expenditures and certification are positively correlated. Firms that invest in R&D often also have a certificate. The effect of R&D investment on certification can be explained in different ways.

R&D investment can improve firms' economic and financial performance (Freihat & Kanakriyah, 2017; Hunady et al., 2020; Pieri et al.,

2018), which could generate enough financial resources to afford certification. The international scope of entrepreneurship relates to frequent entry into new markets, which may necessitate certification. Furthermore, as explained in section 2, R&D activities often generate technological innovation, which can require certification for broad use (Baron & Pohlmann, 2018). The signalling effect of standards can be considered one of the potential reasons that technological innovation and certification to international standards are related. Our results align with previous studies that demonstrated a positive relationship between R&D activities and involvement in standardisation (Blind & Mangelsdorf, 2012; Wakke et al., 2015). Hence, despite the counterarguments and contradictory findings of other previous studies (Sam & Song, 2022), our empirical evidence confirms a direct relationship between R&D expenditures and standards certification. These results also confirm our first research hypothesis.

We introduce several control variables into the model, and the results suggest that most of them have statistically significant effects on certification. For example, we find that certification is more common for larger enterprises, publicly traded companies, firms with foreign owners, enterprises that are in operation using a foreign licence and those in manufacturing, electricity and gas supply. Conversely, sole proprietorships, firms with a female top manager and those with a high share of national sales tend to be certified less often. As expected, significant differences are also evident among the different sectors and countries where businesses operate. Firms operating in Italy, Greece and Bulgaria have a significantly higher probability of certification, which aligns with the findings in the first part of our analysis.

Finally, we examine the factors affecting standards certification and

Table 4
Factors affecting the probability of enterprises' certification.

Variable	Coef./dy/dx (z-stat)
PANEL A: INDIVIDUAL INDEPENDENT VARIABLES	
R&D Expenditures	0.661/0.139 (9.98)***
Size	0.757/0.143 (23.54)***
Part of a large firm	0.249/0.049 (3.78)***
Sole proprietor	- 0.396/-0.07 (-5.15)***
Publicly traded comp.	0.244/0.048 (3.24)***
Capital/main city	0.018/-0.003 (0.29)
Foreign ownership	0.358/0.073 (4.10)***
Female top manager	-0.233/-0.043 (-3.88)***
Having a website	0.845/0.146 (14.4)***
Managers' experience	0.003/0.0006 (1.53)
Direct export share	0.003/0.0005 (1.72)*
National sales share	-0.003/-0.005 (-1.97)**
Foreign licence	0.627/0.131 (10.11)***
PANEL B: DUMMY VARIABLES	
Sector (industry) dummy variables:	
Manufacturing	0.239/0.033 (2.86)***
Electricity, gas	0.484/0.111 (2.47)**
Water supply and waste management	-0.245/-0.065 (-1.60)
Transportation/storage	-0.879/-0.173 (-9.72)***
Accommodation and food service	-0.413/-0.091 (-2.99)***
Information and communications technology (ICT)	-0.915/-0.146 (-6.60)***
Financial services	-0.357/-0.078 (-0.82)
Professional, scientific & technical services	-3.559/-0.154 (-17.6)***
Country dummy variables:	
Albania	0.444/0.092***
Belarus	0.478/0.099***
Belgium	0.753/0.164
Bosna and H.	0.882/0.196***
Bulgaria	1.694/0.392***
Croatia	1.252/0.287***
Cyprus	1.667/0.388***
Czechia	1.095/0.248***
Estonia	0.462/0.096***
Greece	2.334/0.525***
Hungary	1.565/0.361***
Italy	3.198/0.652***
Latvia	0.885/0.197***
Lithuania	0.248/0.05
Luxembourg	0.617/0.133**
Moldova	-0.141/-0.026
Montenegro	1.369/0.318***
North Macedonia	0.643/0.138***
Poland	-0.151/-0.028
Portugal	-0.196/-0.036*
Romania	1.114/0.259***
Russia	-1.146/-0.196***
Serbia	1.347/0.311***
Slovakia	1.141/0.26***
Slovenia	0.917/0.205***
Pseudo-R ²	0.292
Correctly classified	79.24 %
Number of obs.	14,216
Wald chi ²	3094.99

Source: Authors' calculations based on the WBES (2022).

Note: Regressions are estimated using the probit estimator. Standard errors are corrected for heteroscedasticity. ***/**/* denote significance at 1%/5%/10% levels.

R&D expenditures in more detail. In the first step, we use separate probit regression for each dependent variable of R&D expenditures and standards certification. In the second step, we use bivariate probit regression to simultaneously identify the common factors affecting the dependent variables. Several factors can influence the decision to invest in R&D and international standards certification. Based on our results, we expect these decisions to be positively correlated. Based on this, bivariate probit is assumed to be the most viable option for estimating the effects of selected factors. Table 5 summarises the results of the study's single and bivariate probit regressions.

The results of single and bivariate probit regressions are similar. Larger firms tend to invest in R&D and pursue certification more

frequently. The same is true for establishments that are part of a larger firm. The results support the findings of some other previous studies. Larger companies invest more often in R&D (Lee, 2012) due to the ability to cover required fixed costs from sales and superior access to knowledge and human capital.

Foreign ownership positively affects the probability of certification, but is negatively related to R&D expenditure, which aligns with previous studies. Certification is more likely for foreign and group firms due to access to greater resources (Gourlay & Pentecost, 2002) and stringer internal pressure to pursue certification (Pekovic, 2010). In contrast, foreign ownership reduces the likelihood that a firm will invest in R&D because most R&D expenditures are in the firm's home country (Zemplerová & Hromadová, 2012). However, when a firm's business is conducted with a licence from abroad, this has a positive effect on R&D expenditure and standards certification. This may be attributable to international co-operation and pressure on quality signalling and interoperability. The findings concerning export focus are also notable. Firms with a dominant share of sales from the domestic market are less likely to invest in R&D or obtain an internationally recognised certificate. Most of the variables have the same sign and statistical significance as their regression coefficients in both types of regressions. Similar effects on R&D expenditure and standards certification are also found for most variables except those regarding firms' sector. Therefore, our second research hypothesis is validated. In contrast, significantly distinct effects on R&D expenditures and standards certification are found when comparing different sectors. Manufacturing firms and firms with primary business in electricity, gas, steam distribution and water supply appear to be less likely to invest in R&D but more likely to pursue a certificate. In general, we can assert that differences among sectors are significant, which confirms our third research hypothesis. It seems that the type of sector can be considered a factor that affects R&D expenditures compared with international standards certification.

Conclusions

The results of our analysis with a focus on R&D and standards certification provide several relevant insights. As demonstrated in sections 1 and 2, both approaches are closely correlated with enterprises' sustainable innovation, sustainable entrepreneurship and technological advancement. As asserted in the introduction, both concerns are closely related to sustainable innovation, sustainability and technological progress in entrepreneurship. Specifically, our results demonstrate a clear relationship between international standards certification and investment in R&D. It appears to be evident that firms investing in R&D tend to be more frequently certified to international standards, which is particularly evident for ISO 14,000 certificates focused on environmental management. The ISO 14,000 and ISO 9000 families of standards are most commonly adopted by the establishments in our sample and are closely related to sustainable innovation and meeting several of the UN SDGs. Similarly, R&D activities often lead to the adoption of new technology and sustainable innovation. Such innovative products can further benefit from standards certification due to enhanced interoperability and quality signalling.

Our results also suggest that firm characteristics such as size, international licensing and export focus affect enterprises' R&D investment and the acquisition of internationally recognised certifications, confirming that larger firms, firms with foreign licences and those focused on export are more likely to invest in R&D and pursue internationally recognised certificates. These factors also indirectly affect firms' capabilities to develop sustainable innovation and adopt new sustainable technologies. This finding also supports our assumption concerning interconnections between both approaches. However, we also identify significant differences in R&D expenditures and standards certification between sectors. This could be the result of sector clustering of R&D expenditures, which is different from typical sector clustering based on certification. Hence, we contend that these two approaches should be

Table 5
Single and bivariate probit regressions.

	R&D expenditures		Certification		Marginal effects (dy/dx) bivariate probit
	Single probit	Bivariate probit	Single probit	Bivariate probit	
Size	0.267***	0.263**	0.456***	0.456***	0.031***
Part of a large firm	0.142***	0.150***	0.149***	0.151***	0.016***
Sole proprietor	-0.174***	-0.203***	-0.236***	-0.237***	-0.017***
Publicly traded comp.	0.0004	0.03	0.144***	0.143***	0.005
Capital/main business city	0.122***	0.016***	0.013	0.014	0.007**
Foreign ownership	-0.001**	-0.001**	0.002***	0.002***	-0.00005
Female top manager	-0.087**	-0.092**	-0.137***	-0.138***	-0.00****
Having a website	0.475***	0.472***	0.491***	0.489***	0.037***
Managers' experience	0.0009	0.0007	0.002	0.002	0.00001
Share of direct export	0.002*	0.002*	0.002*	0.002**	0.0002**
Share of national sales	-0.003***	-0.003***	-0.002**	-0.002**	-0.0003***
Foreign licence	0.592***	0.592***	0.418***	0.418***	0.072***
Sector (industry) dummy variables					
Manufacturing	-0.541***	-0.566***	0.520***	0.522***	-0.014**
Electricity, gas, steam	-0.470***	-0.489***	0.660***	0.667***	-0.012***
Water supply & waste	-0.722***	-0.736***	0.234*	0.230*	-0.026***
Wholesale and retail	-0.942***	-0.978***	0.350***	0.352***	-0.031***
Transport. & storage	-0.863***	-0.884***	-0.133	-0.130	-0.044***
Accommodation & food	-1.176***	-1.16***	0.127	0.129	-0.034***
ICT	-1.001***	-1.04***	-0.181	-0.187	-0.034***
Financial services	-0.632**	-1.05***	0.111	0.131	-0.031***
Number of obs.	14,477	14,216	14,248	14,216	
Wald chi ²	1810.8	5093.0	3495.9	5093.0	
ρ value (bivariate probit)		0.207		0.207	
Wald test ρ = 0		95.07***		95.07***	

Source: Authors' calculations based on the WBES (2022).

Note: Regressions are estimated using probit and bivariate probit estimators. Standard errors are corrected for heteroscedasticity. ***/**/* denote significance at 1%/5%/10% levels. Country dummies are included but not shown.

considered highly diverse from a sectoral division perspective. It appears that different industries have distinct decision-making criteria concerning R&D investments and international standards certification.

Despite our best efforts to identify the most relevant results, our research approach has some notable limitations. Limitations are apparent regarding data availability for the examined period and countries captured in the sample, which limits our approach to cross-sectional data analysis. Furthermore, the data and methodology used do not allow us to make direct claims concerning causal relationships due to potential endogeneity problems. Since the variables examined appear to be correlated, we use a bivariate probit approach, which has the advantage of considering the correlation between the error terms in the two equations. Hence, this approach allows us to examine the set research problems to a certain level; however, we assert that a more detailed examination of the potential reverse causality between R&D expenditure and certification can be addressed in future research. Moreover, future research that focuses more specifically on sustainable innovation, sustainable technology and regulatory frameworks could further enhance the understanding of key findings concerning sustainability issues.

CRedit authorship contribution statement

Ján Hunady: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Veronika Chyláková:** Writing – review & editing, Visualization, Data curation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Jan Hunady reports financial support was provided by Slovak Research and Development Agency.

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Supplementary materials

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