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SUSTAINABLE UNIVERSITY – KNOWLEDGE AND TECHNOLOGY TRANSFER CHANNELS TO ENTERPRISES

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ABSTRACT: The main aim of the article is an empirical verification of the channels through which the transfer of knowledge and technology from technical universities to enterprises takes place. The specific objective is to indicate the forms in which scientists can transfer knowledge and technology to enterprises in the field of sustainable solutions. In order to identify the features of the hidden dimensions of the university-enterprise relationship, the exploratory factor analysis (EFA) was used. The factor analysis showed that there are 3 channels through which scientists from technical universities establish relations with enterprises: the consulting and educational channel, the scientific and information channel, and the research and commercialization channel. In each of these channels, forms of knowledge and technology transfer have been identified that may relate to environmental topics for enterprises.

KEYWORDS: university-industry relations, KTT (knowledge and technology transfer), interaction channels, sustainable university

Introduction

The interest in university-industry interactions has been the subject of many studies (Nelson et al., 2002; Laursen & Salter, 2004; D'Este & Patel, 2007; Brimble & Doner, 2007; Segarra-Blasco & Arauzo-Carod, 2008; Tether & Tajar, 2008; Skute et al., 2019; Perkmann et al., 2021). Contrasting views on the role of universities in this process and the desired relationship between universities and businesses emerged from these articles. While commercialisation is the main form of knowledge transfer from science to business, there are many other engagement channels through which scientists can interact with companies (Schartinger et al., 2001; Agrawal & Henderson, 2002; Cohen et al., 2002; Mowery & Sampat, 2005; Perkmann et al., 2013, Perkmann et al., 2021).

As demonstrated by, for example, Meyer-Krahmer and Schmock (1998), as well as D'Este et al. (2005), university researchers decide to interact with industry (in addition to accessto additional income from research) to ensure the application of research results in practice, access to industrial facilities and keeping abreast of industry issues (D'Este et al., 2005). It is unlikely that any single form of interaction can satisfy a wide range of motivations. For example, consulting scientists for companies can bring additional income, and joint research projects will give scientists access to skills and facilities that are owned by the industry. This means that scientists motivated to interact with industry will likely do so through a variety of forms/channels rather than through a single mechanism. Such diversity enables them to reap greater benefits, both financial (e.g. income from research) and non-monetary (e.g. satisfaction from access to research).

The literature on the subject provides a lot of evidence for various forms of activity of scientists in the field of knowledge and technology transfer to other sectors (Perkmann et al., 2013; Rothaermel et al., 2007). There is no doubt that there are numerous forms of such involvement (Perkmann et al., 2019; D'Este & Patel, 2007; Link et al., 2007). However, empirical research focuses mainly on activities related to commercialisation, described by some researchers as formal channels of knowledge and technology transfer (Rothaermel et al., 2007). At the same time, the literature does not present a uniform typology of forms/mechanisms in which they can undertake such cooperation.

In recent years, the concept of a sustainable university has appeared in the literature, according to which the university integrates all its activities in accordance with the principle of sustainability to contribute to the sustainable development of stakeholders (Velazquez et al., 2006; Lozano, 2010). This article contributes to the development of research based on stakeholder the-

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ory in universities (Miller et al., 2014), taking into account the role of cooperation universities with enterprises to ensure sustainable development. A sustainable university's relationship with the business sector is crucial for promoting sustainability, driving innovation, and creating a positive societal impact (Lee, 2000). Moreover, sustainable cooperation between universities and businesses can be implemented through various knowledge and technology transfer channels.

The main aim of the article is an empirical verification of the channels through which the transfer of knowledge and technology from technical universities to enterprises takes place. The specific objective is to indicate the forms in which scientists can transfer knowledge and technology to enterprises in the field of sustainable solutions. The research was conducted among scientists from technical universities in Poland.

The article consists of 4 sections: in the first section, a literature review was conducted. In the second section, special emphasis has been placed on the systematics of forms developed in the literature, in which scientists transfer knowledge and technology to enterprises. The third part describes the research methodology: the Exploratory Factor Analysis (EFA) used in the study, the research tool and the measurement method were presented. The research sample was analysed. The next section describes the results of the research. Then, the results of the study and the summary were discussed.

Literature review

Main insight into industry-university cooperation

Establishing cooperation between the science sector and enterprises has become the subject of many scientific studies for various reasons (Perkmann et al., 2013; D'Este & Perkmann, 2011; Perkmann & Walsh, 2009; Azagra-Caro et al., 2006; Owen-Smith et al., 2002). First of all, the public research system (consisting of higher education institutions and other public research and innovation organisations) plays a key role in generating and developing the knowledge that innovative enterprises need and enables them to use the results of activities undertaken as part of scientific research. Researchers on the subject indicate that the cooperation of representatives of science and business includes various mechanisms and forms of knowledge transfer (Bozeman et al., 2013). Empirical research is focused mainly on the ability of universities to exploit IPR through patent ownership agreements, academic spin-offs, licensing, and joint research projects with industry (D'Este et al., 2005), but also take into account such cooperation mechanisms as staff mobility, informal contacts, consulting relations, informal exchange of information and training for enterprises (Brimble & Doner, 2007; Mathews & Hu, 2007).

The literature on the subject has, to some extent, determined the determinants of cooperation between scientists and enterprises, in particular from the perspective of scientists. Many researchers, after in-depth literature research, state that individual factors (related to the person of the scientist) explain scientists' involvement in cooperation to a greater extent than other factors, e.g. public policies or institutional support (D'Este et al., 2005). As the results of other studies show, male scientists are much more likely to engage in relations with enterprises (Feldy, 2014). The influence of age and seniority has not been clearly defined in studies (Boardman & Ponomariov, 2009; D'Este & Patel, 2007; Feldy, 2014). Given that a researcher's involvement in cooperation with the business sector is often linked to personal contacts, more experienced researchers are likely to have wider contacts, which will allow them to find potential partners for their projects in the private sector (Haeussler & Colyvas, 2011). Past experience of collaboration will positively influence scientists' attitudes towards the industry as well as their collective behaviour (D'Este & Patel, 2007). These results are supported by research that previous experience with commercialisation, patenting or creating joint research ventures increases the likelihood of scientists participating in joint activities (Bekkers & Freitas, 2008). Various studies indicate the complementarity between obtaining grants by scientists and funds obtained from industry (Boardman & Ponomariov, 2009; Bozeman & Gaughan, 2007; Lee & Bozeman, 2005). In addition, the ability to raise public funds may indicate an overall ability to attract funds, which will also increase the likelihood of moving to collaborative projects with industry (Sá et al., 2017).

Channels of knowledge and technology transfer from university to industry

After an in-depth review of the literature, a summary of various approaches to defining knowledge and technology transfer channels/mechanisms can be made. These typologies differ in nomenclature categorisation depending on the research teams and conducted research.

For example, Mathieu (2011) points out that there are traditional and modern, formal and informal mechanisms of knowledge transfer to industry. He believes that researchers should be encouraged to engage in non-formal forms of knowledge transfer in order to effectively transfer knowledge to industry. On the other hand, Hermans and Castiaux (2007) distinguish between directed and undirected forms of interaction. There is a group of researchers who consider the mechanisms of knowledge and technology transfer due to the degree of formality and the depth of contacts (Schartinger et al., 2002; D'Este & Patel, 2007; Wright et al., 2008; Perkmann & Walsh, 2009; Eun, 2009; Cassiman et al., 2010; Leisyte, 2011), degree of interaction (Fritsch & Schwirten, 1999; Perkmann & Walsh, 2007; Santoro & Saparito, 2003; Schartinger et al., 2002; Wright et al., 2008), direction of knowledge flow (Schartinger et al., 2002; Arza, 2010), the potential forresults (Wright et al., 2008; Perkmann & Walsh, 2009). Studies by authors such as Gaughan and Bozeman (2007) and Tartari and Salter (2015) indicate the following forms of involvement of scientists in cooperation with industry (apart from strictly commercial activities): (1) attendance at the conference with industry, (2) attendance at industry-sponsored meetings, (3) a new contract research agreement, (4) a new joint research agreement, (5) a new consultancy agreement, (6) postgraduate training with industry, (7) training of company employees, (8) creation of new physical facilities with industry funding. Other studies (Arvanitis et al., 2008) categorised the forms of knowledge and technology transfer from universities to enterprises into more synthetic groups and indicated 5 types of knowledge and technology transfer: informal (e.g. informal contacts; conferences, workshops; scientific publications of the business sector); infrastructural (activities related to the use of technical facilities); educational (contacts with graduates employed in the business sector, participation in R&D projects, projects of diploma and doctoral theses in cooperation with companies, joint didactic courses, didactic classes for business); research (cooperation projects, long-term research contracts, research consortia); consulting (expert opinions/reports for business).

Table 1. Mechanisms/forms of interaction between universities and enterprises in the light of the literature on the subject

Mechanisms/types of interactions	Number of articles
Consulting	18
Contract research	13
Joint research	13
Informal contacts/advice	8
Training of personnel	8
Placement/supervision of students	8
Industry funding	8
Joint publication	7
Conferences/workshops	7
Membership in advisory boards	5
Joint creation of physical facilities	3
Work with standardization bodies	2

Source: authors' work based on Perkmann et al. (2021).

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Perkmann et al. (2019) conducted a systematic review of the literature and, based on it, identified the most common forms of involvement of scientists in cooperation with enterprises. Table 1 summarises the mechanisms/forms of knowledge and technology transfer from universities to enterprises identified in previous literature studies. As the analyses in the table show, some cooperation mechanisms are more popular among researchers, e.g. joint scientific publications, participation of scientists in conferences organised by the industry, consulting services, and spin-off companies.

Gripme and Hussinger (2013) argue that most existing research has focused on formal technology transfer mechanisms, i.e. those that embody or directly lead to effects, such as a patent or license. Only a few authors have studied informal university technology transfer mechanisms that focus on contractual forms of partner involvement. These researchers distinguish between formal mechanisms implemented in cooperation with enterprises, such as contract research, technological consulting, licensing and technology acquisition, and informal mechanisms as "non-contractual contacts between companies, universities and society". Studies have shown that informal contacts improve the quality of formal contacts or that formal agreements are accompanied by an informal relationship related to the transferred technology. Their research in German enterprises confirms this complementary relationship. Similar research results were published by Boardman and Ponomariov (2007). Researchers involved in informal interactions with industry are more likely to engage in collaborative research with the commercial sector than researchers who do not engage in such informal relationships. In particular, this applies to such informal contacts as co-authorship of publications, private consulting for companies or informal cooperation with industry in the field of applied research.

Sustainable university concept and role industry-university cooperation

The concept of a "sustainable university" is an issue of growing interest in the scientific literature (Velazquez et al., 2006). There is no exact date when the concept originated, as it is a developing idea that has evolved as research has progressed and societal priorities have changed. However, it can pointed out that the concept gained prominence in the 1990s and early 2000s as many educational institutions around the world began to engage with sustainability and innovate their curricula and operations (Lukman & Glavič, 2007; Lozano et al., 2013). Most of the most frequently cited publications come from the USA, Brazil and Germany (Web of Science database). The most cited article (394 citations in WoS) is "Sustainable university: what can be the matter" (Velazquez et al., 2006) from the "Journal of Cleaner Production". The next two positions also contain articles from this journal:

- from 2012: *Academic staff development as a catalyst for curriculum change towards education for sustainable development: an output perspective* (Barth & Rieckmann, 2012),
- and from 2015: *Sustainable universities – a study of critical success factors for participatory approaches* (Disterheft et al., 2015).

In the case of Polish publications and research on the topic of "sustainable university", there are few of them, except for the publications by Budzanowska-Drzewiecka et al. (2023), Sułkowski et al. (2020) and Sady et al. (2019). Polish authors focus in their research on the importance of shaping a sustainable organisational culture of universities, the role of universities in developing sustainable-oriented competencies and initiatives undertaken by Polish universities towards the implementation of ESG principles.

There have been different approaches to the topic of a sustainable university (Deleye, 2023). One approach is the idea of a sustainable university, which emphasises the role of universities in solving global environmental problems through education, research and community involvement (Gamze, 2023; Sart, 2022; Lambrechts et al., 2013). Another approach is the concept of an engaged community, where universities actively engage their stakeholders in sustainable development initiatives (Deleye, 2023). In turn, in another discourse, there is the idea of a green-tech campus focusing on the inclusion of sustainable technologies and practices in the university's activities (Deleye, 2023; Anthony, 2021).

One of the most cited definitions of a sustainable university is proposed by Velazquez et al. (2006) – forthis author, a sustainableuniversity is "*a HEI (…) that addresses, involves and promotes, on a regional or a global level, the minimisation of negative environmental, economic, societal, and health effects generated in the use of their resources in order to fulfil its functions of teaching, research, outreach and partnership, and stewardship in ways to help society make the transition to sustainable life-styles*". Higher Education Institutions sustainable initiatives and activities could take place in different areas (e.g., Fischer et al., 2015; Lozano et al., 2013): research, education, campus operations, community engagement/outreach, institutional framework, on-campus experiences, and assessment and reporting. Measurement methods of sustainable universities differ in typology, number of indicators and methodology of integrating sustainable development into university performance (Nejati & Nejati, 2013; Lozano et al., 2013; Nagy & Veresne Somosi, 2020; Gómez et al., 2023). Nagy et al. (2022) considered 3 evaluation criteria of a sustainable university: sustainable strategy, sustainable operations/infrastructure and sustainable actions/education/research. Dimensions of the measuring tools proposed by Lozano include the institutional framework, campus operations, sustainable development in education, research, outreach ad collaboration, on-campus experience (Lozano et al., 2013).

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Universities can play an important role in solving global environmental problems through research, education and cooperation with the business sector to jointly seek pro-ecological solutions (Panait et al., 2022). In the literature, it is underlined that universities have the knowledge and power to lead change towards a more sustainable world (Rotondo et al., 2023). Today, many universities are committed to sustainability by engaging in activities such as reducing carbon emissions, promoting sustainability research, introducing sustainability-related courses and curricula, and taking other measures to promote sustainable practices on their campusesand beyond (Lukman & Glavic, 2007). Including sustainable development issues in study programs is important to ensure high-quality education and contribute to the implementation of the Sustainable Development Goals (Gigauri et al., 2022). Nowadays, universities incorporate elements of sustainable development into their strategic plans as well, focusing on goals such as high-quality education and resilient infrastructure (Abello-Romero et al., 2023). Reaching a consensus on a single approach to sustainable development is not possible due to the complexity of the issues and the need to involve many stakeholders, including enterprises (Sastre Segovia et al., 2023). The Sustainable Development Goals can be achieved through strong partnerships between academia and industry (Bodley-Scott & Oymak, 2022). Universities have the potential to address sustainability challenges through academic and structural innovations (Serna et al., 2022). The transfer of knowledge and technology from universities to enterprises is an important aspect of sustainable development (Padilla Bejarano et al., 2023). Tech companies' strategies, such as investing in faculty development and fostering their entrepreneurial culture, can help universities achieve sustainability (Văduva et al., 2022). From the perspective of inter-sectoral cooperation (university-business), joint research and education on sustainable technologies are particularly important, but also shaping appropriate attitudes, behaviours and policies for sustainable development.

At least two other concepts of a university entering into relations with its environment can be found in the literature: e.g. "civic university" (ability to integrate its teaching, research and engagement with the outside world in such a way that each enhances the other without diminishing their quality; Goddard et al., 2016) and "community-engaged universities" (refers to an approach in which universities and educational institutions engage with their local communities and the surrounding world; Cook & Nation, 2016). "Civic university", "sustainable university", and "community-engaged university" are three different concepts and approaches to the functioning of universities that often coexist but are not identical. Many universities strive to be both civic universities, sustainable universities and community-engaged universities. These activities can complement each other. A civic university

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can engage in sustainability projects, which makes there some overlap between the two concepts. A community-engaged university is often part of a civic university because active cooperation with the local community is often an important element of the role of a civic university. It is worth noting that these concepts may be implemented differently by different universities, and their meaning may vary depending on the regional and local context.

Research Methodology

Exploratory factor analysis

These studies were performed using an EFA (Exploratory factor analysis). EFA is a statistical technique that allows to create (if possible) of a smaller pool of variables (usually several dimensions) according to a given criterion. It allows, when reducing the number of variables, to describe a given process or phenomenon while maintaining the maximum level of information (Hayton et al., 2004). The method was used to reduce the dimensionality of the data. Minimising the number of variables needed to explain a given variable simplifies the interpretation of the results (Taherdoost et al., 2022).

The goal of exploratory factor analysis is to use the existing variables to create dimensions that best explain the variance (or variability) of the scores of all the variables that were considered in the analysis. The calculations are based on the r-Pearson correlation coefficient. The theoretical basis of exploratory factor analysis is that if one group of questions measures a given construct, then the answers to these questions should be correlated with each other. An exploratory analysis can also be performed when there are no assumptions as to the result (Bedyńska & Brzezicka, 2007). Conditions that must be met by variables used in factor analysis (Brown & Moore, 2012): (1) they should be measured on an interval or ratio scale, (2) appropriate research samples should be used. It is recommended that there be at least four or five times as many observations (sample size) as there are variables; (3) the basis of the analysis is the correlation matrix between the variables. In the case of factor analysis, these variables should be correlated.

Measures and instrument

To understand the factors shaping collaboration channels, used a quantitative method of collecting and analysing data was used. The survey was used to collect information. Due to the research gap existing in the literature related to the measurement of the involvement of scientists in cooperation with enterprises, an interpretation and measurement of this phenomenon was made. When conceptualising the variable academic involvement in cooperation with enterprises, it was assumed that it is a construct consisting of certain dimensions, and the indicators of their variables are reflective. A factor approach was used to construct the measurement scale of scientists' involvement as an unobservable phenomenon.

The survey consists of two parts: general questions (gender, work experience, discipline, etc.) and of 18 questions with five alternative responses[1].

Table 2. List of statements and dimensions of the questionnaire researching the involvement of scientists in cooperation with enterprises

No	Statement	Predetermined form/channel of cooperation
1	A private company asked me for information about my research, and it was shared with them	INFORMATIONAL
2	I have contacted people from the industry about their research or research interests for cooperation	
3	I assisted in employing graduates or PhD students in enterprises	
4	I was a co-author of a publication with people from the business sector that was published in a journal or peer-reviewed conference proceedings	
5	I have developed scientific publications on solving problems in enterprises	
6	I participated in conferences and workshops organized by the business sector and presented the results of my research	
7	I was a paid consultant in a private company	CONSULTING
8	I had any relationship (in terms of consulting) with a company from the private sector (e.g. I consulted over the phone how to solve a problem for the company)	
9	I was the author of reports and expert opinions for business	
10	I cooperated (conducted research) directly with the enterprise in order to commercialize and transfer technology	RESEARCH
11	I carried out a research and development project together with the industry	
12	I used the technical infrastructure of an external company for my scientific research	
13	Classes in my subject were conducted by a practitioner from the company I work with	EDUCATIONAL
14	I participated as an author or promoter in the development of an implementation doctorate	
15	I conducted commercial trainings for the company	
16	I worked in a company (SPIN-OFF) in which I am the owner, partner or employee	COMMERCIALIZATION
17	I cooperated directly with the company and this cooperation resulted in a patent or copyright	
18	I participated in the sale of a license for an invention or industrial design	

1 In the measurement questionnaire, the variable "Involvement in cooperation with enterprises" was examined with the question: Over the last 3 years, have you cooperated with enterprises in the forms listed below? Please rate how often the following situations have occurred in the last 36 months? (1 – 0 times; 2 – 1-2 times; 3 – 3-5 times; 4 – 6-9 times; 5 – 10 times and more.

Based on the literature review, it was noted that the existing scales for measuring the involvement of scientists in cooperation with enterprises are limited and do not comprehensively cover all possible forms of cooperation. As a result, their own constructs were developed as a tool to measure the forms in which scientists can engage in cooperation with enterprises. Based on the literature review, the most common forms of cooperation between scientists and enterprises were identified. The theorems were developed on the basis of measurement scales contained in publications by such authors as: (Bozeman & Gaughan, 2007; Arvanitis et al., 2008; Tartari et al., 2014; Tartari & Salter, 2015; Iorio et al., 2017). As a result, a scale for measuring involvement in cooperation was developed, consisting of 18 statements (Table 2), for which the respondent could select the answer that best described their situation regarding cooperation with the company in the last 3 years in the field of a given position. Initially, it was assumed that there are 5 channels through which scientists transfer knowledge to industry: information, research, education, commercialisation and consulting.

Seeking to identify the data structure to reduce the number of variables and to check the dimension variability of each research construct, exploratory factor analysis using varimax rotation was performed. Due to the low correlation with other items, 7 items were excluded from the analysis. In the final solution, only items with loading values above 0.5 were considered.

The use of factor analysis made it possible to isolate a small number of theoretical constructs (factors) that cannot be measured directly and which are presented by observable indicators (respondents' answers to individual questions in the questionnaire).

Data analysis was performed using SPSS Statistics 21.0 software and IBM SPSS Amos 21.0.

Sample and data collection

A group of Polish technical universities was selected for research and empirical analyses. According to the classification of the Ministry of Science and Higher Education (MNiSW), there are 18 public technical universities in Poland. All of them are public schools that operate on the basis of the same regulations, offer similar sets of fields of study, and are mainly aimed at educating engineers and developing science in technical fields. Despite some diversification of their size and set of fields of study, due to the declared dominant technical profile, they can be treated as a homogeneous group. Universities of technology conduct research, often financed from public funds, in areas that have a decisive impact on innovations in high-technology industries, e.g. pharmaceutical, chemical or electronic. It should be emphasised that so far in Poland, no such extensive research has been carried out in the

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context of possible forms and channels of knowledge transfer from universities to enterprises. The last large research on cooperation was published in 2016 (Trzmielak et al., 2016), in which the author pointed out the motives and barriers of such cooperation and compared selected forms of knowledge transfer preferred by Polish researchers with those of international scientists.

The literature also emphasises the need to integrate research activities with the processes of educating staff for industry because only thanks to highly qualified graduates innovative solutions can translate into economic benefits and thus into economic growth of the country (Mansfield, 1995; Salter & Martin, 2001). It is also an important argument justifying attempts to study the effectiveness of this area of activity of technical universities. Data for statistical analyses were obtained using CAWI method and sending link to questionnaire to scientists' e-mails obtained from the websites of universities, faculties, and departments. The sample size counts 526 respondents and meets the minimum rule of ten times the number of observed variables (items) in quantitative research using a questionnaire (with a total of 18 predictive items observed).

Detailed characteristics of the research sample are included in Table 3.

According to the data obtained from the sample, men predominated among the respondents (64.5%). 35.5% of women took part in the survey. This proportion seems to be in line with the actual gender distribution in the scientific community (Feldy, 2014). The sample was dominated by academics with work experience at their university between 16 and 25 years (28.6%), and the fewest respondents worked at the university for up to 3 years (7.2%). More than 40% of the sample were scientists with a PhD degree. The smallest group of respondents had a master's degree (4%). The group of respondents was dominated by people representing the field of engineering and technical sciences (71.3%), which is justified by the specificity of technical universities and the fact that they mainly offer engineering and technical faculties. In the study, the least numerous group were representatives of agricultural, forestry and medical sciences (4.6%), included in the group of respondents of other sciences. The surveyed scientists, in particular, conducted basic research (58.1%), followed by applied (48.7%) and R&D (45.2%). Most of them have not implemented a grant from the National Science Center or the National Center for Research and Development in recent years (52.3%).

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Table 3. The structure of the research sample

Gender	No of responses	% responses	Seniority	No of responses	% responses
Man	351	64.5%	1-3	38	7.2%
Women	175	35.5%	4-8	96	18.2%
Academic degree/title			9-15	128	24.4%
Master	11	4%	16-25	150	28.6%
Msc	47	8.9%	Over 25	114	21.6%
PhD	49	9%	**Research field of the respondent**		
PhD Eng.	223	41%	Engineering and technology	388	71.3%
Post-doctoral degree	29	6.6%	Social	85	15.6%
Post-doctoral Eng. degree	119	21.7%	Natural sciences	45	8.6%
Professor	48	8.8%	Others	8	4.6%
Type of research conducted (all types of research should be indicated)			**Implementation of the grant (in the last 3 years)**		
Basic	305	58.1%	Yes	251	47.7%
Applied	256	48.7%	No	275	52.3%
Industrial	180	34.3%	**Experience of working in an enterprise**		
R&D	238	45.2%	Yes	221	42.1%
Does not conduct research	12	2.2%	No	305	57.9%
The number of companies with which the scientist has cooperated in the last 3 years			**Cooperation of the respondent with enterprises (in the last 3 years)**		
0	65	12.4%	Yes	487	92.5%
1-2	212	40.4%	No	39	7.5%
3-5	159	30.1%			
6-9	48	9.2%			
10 and more	42	7.9%			

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Research results

Table 4 contains a summary of the types of relationships and the frequency of responses for scientists who have been involved in a given type of cooperation in the last 3 years.

Table 4. Types of academic engagement in cooperation with enterprises and response frequency(N=526)[2]

Variable/Frequency	Frequency – answer 'Yes"	0 times	1-2 times	3-5 times	6-9 times	10 times and more
Z1 a private company asked me for information about my research, and it was shared with them	50.7%	49.3%	27.4%	13.2%	3.5%	6.6%
Z2 I have contacted people from the industry about their research or research interests for cooperation	63.5%	36.5%	30.9%	17.6%	6.4%	8.6%
Z3 I assisted in employing graduates or PhD students in enterprises	59.5%	40.5%	29.8%	17.8%	6.6%	5.3%
Z4 I was a co-author of a publication with people from the business sector that was published in a journal or peer-reviewed conference proceedings	47.6%	52.4%	30.1%	11.6%	3.5%	2.4%
Z5 I have developed scientific publications on solving problems in enterprises	51.9%	48.1%	30%	14.3%	3.9%	3.7%
Z6 I participated in conferences and workshops organized by the business sector and presented the results of my research	46.7%	53.3%	26.5%	12.9%	4.2%	3.1%
Z7 I was a paid consultant in a private company	46.2%	53.8%	22.2%	14.2%	2.8%	7%
Z8 I had any relationship (in terms of consulting) with a company from the private sector (e.g. I consulted by phone how to solve a problem for the company)	81.3%	18.7%	24.4%	22.6%	11.9%	22.4%
Z9 I was the author of reports and expert opinions for business	64.2%	35.8%	28.5%	21%	5.7%	9%
Z10 I cooperated (conducted research) directly with the enterprise in order to commercialize and transfer technology	44.5%	55.5%	29.4%	7.2%	3.3%	4.6%
Z11 I carried out a research and development project together with the industry	51.1%	48.9%	32.7%	14.7%	2.2%	1.5%

2 In the measurement questionnaire, the variable "Involvement in cooperation with enterprises" was examined with the questions: Over the last 3 years, have you cooperated with enterprises in the forms listed below? (Yes/No) and How often did you have contact with the company in various forms of cooperation (0 times, 1-2 times, 3-5 times, 6-9 times, over 10)?

Variable/Frequency	Frequency – answer 'Yes"	0 times	1-2 times	3-5 times	6-9 times	10 times and more
Z12 I used the technical infrastructure of an external company for my scientific research	37.1%	62.9%	22.8%	8.3%	2.9%	3.1%
Z13 classes in my subject were conducted by a practitioner from the company I work with	35.8%	64.2%	20.4%	8.6%	2.4%	4.8%
Z14 I participated as an author or promoter in the development of an implementation doctorate	12.7%	87.3%	9.9%	2.4%	0.2%	0.2%
Z15 I conducted commercial trainings for the company	34.5%	65.5%	21.5%	7.2%	2.9%	2.9%%
Z16 I worked in a company in which I am the owner, partner or employee	14.3%	85.7%	10.8%	1.3%	0.4%	1.8%
Z17 I cooperated directly with the company and this cooperation resulted in a patent or copyright	34.8%	65.2%	23%	6.1%	2.6%	3.1%
Z 18 I participated in the sale of a license for an invention or industrial design	12.8%	87.2%	9.7%	1.8%	0.6%	0.7%

Source: authors' work based on research results.

An analysis of correlations between the examined variables was also carried out. On the basis of the correlation matrix, it was noticed that each statement correlates with at least one other statistically significantly. This is confirmed by the determinant of the correlation matrix of 0.0000311. A very low value of the determinant means that there are many significant correlations between the analysed variables and there are probably factors connecting these variables. Also, the high value of the Kaiser-Mayer-Olkin measure – 0.911 indicates good data properties (Table 5).

Table 5. Correlation matrix properties: Bartlett's sphericity test and Kaiser-Mayer-Olkin coefficient

Kaiser-Mayer-Olkin Bartlett tests		
KMO measure of sampling adequacy		0.911
Bartlett's sphericity test	Approximate chi-square	3663.381
	Df	153
	Sig.	.000

Taking into account the Kaiser criterion (eigenvalue greater than 1), 4 factors should be distinguished. Together, these factors explain 59% of the variance of the output variables. Using the matrix of factor loadings, insignificant indicators were removed, i.e. those which in no dimension had a factor

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loading with an absolute value greater than 0.449 and indicators that were not clear from the point of view of a given factor (without substantive justification). Due to low correlations with other variables, 7 indicators were excluded from the analysis. In the process of identifying the number of factors, a factor analysis was performed using the principal components technique with Varimax rotation. The number of common factors was determined using the Kaiser criterion. The final application of factor analysis made it possible to isolate 3 hidden variables expressing the involvement of scientists in various forms (channels) of cooperation, for which names (symbols) were assigned: EC consulting and education, research and commercial (RC), scientific and informational (SI) (Table 6).

Table 6. Matrix of rotated factors containing factor loadings for individual items of the scale (after rotation with the Varimax method)

Matrix of rotated components			
	Channels/Forms		
	1(EC)	2(RC)	3(SI)
Z7 I was a paid consultant in a private company	.701	.208	.139
Z8 I had any relationship (in terms of consulting) with a company from the private sector (e.g. I consulted by phone how to solve a problem for the company)	.660	.284	.246
Z9 I was the author of reports and expert opinions for business	.621	.199	.294
Z15 I conducted commercial trainings for the company	.449	.134	.312
Z10 I cooperated (conducted research) directly with the enterprise in order to commercialize and transfer technology	.348	.686	.147
Z 18 I participated in the sale of a license for an invention or industrial design	.061	.685	.098
Z17 I cooperated directly with the company and this cooperation resulted in a patent or copyright	```	.612	.247
Z11 I carried out a research and development project together with the industry	.330	.548	.253
Z5 I have developed scientific publications on solving problems in enterprises	.248	.080	.725
Z4 I was a co-author of a publication with people from the business sector that was published in a journal or peer-reviewed conference proceedings	.192	.259	.701
Z6 I participated in conferences and workshops organized by the business sector and presented the results of my research	.285	.274	.656
Extraction Method: Principal Axis Factoring. Rotation Method: Varimax with Kaiser Normalization.			

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From the factor analysis, it turned out that the channels/form of knowledge transfer defined in the initial theoretical assumptions for the involvement of scientists in cooperation are interrelated, and so, for example, the activities of scientists within the educational channel can be combined with consulting involvement (EC dimension); commitment focused on research is closely related to commercialisation cooperation of scientists (RC dimension); activities aimed at transferring information from researchers to enterprises (e.g. in the form of research results) can be further specified as a science and information channel (SI dimension).

From the factor analysis, the obtained results show that the involvement of scientists in cooperation with enterprises, measured by the discussed fragment of the research questionnaire, is expressed through various activities and initiatives grouped into specific channels (dimensions/forms), which group a relatively homogeneous set of information regarding specific involvement of the scientist in cooperation.

The factor analysis indicated that academic engagement includes the following dimensions and the measurement scales that create them:

- *Consulting and Educational Channel (CE)* – this factor is determined by indicators defining the activities of scientists, expressed by variables such as Z7 (I was a paid consultant in a private company), Z8 (I had any relationship (in terms of consulting) with a company from the private sector, Z9 (I was the author of reports and expert opinions for business) and Z15 (I conducted commercial training for the company),
- *Research and Commercialization Channel (RC)* – this factor was determined by indicators Z10 (I cooperated directly with the enterprise in order to commercialise and transfer technology), Z11 (I carried out a research and development project together with the industry), Z17 (I cooperated directly with the company and this cooperation resulted in a patent or copyright), Z18 (I participated in the sale of a license for an invention or industrial design),
- *Scientific and Information Channel (SI)* – this factor approximates the involvement of scientists in scientific and information forms of cooperation with enterprises: variables Z4 (I was a co-author of a publication with people from the business sector that was published in a journal or peer-reviewed conference proceedings), Z5 (I have developed scientific publications on solving problems in enterprises), Z6 (I participated in conferences and workshops organised by the business sector and presented the results of my research).

The reliability of the scales created on the basis of the EFA was assessed using the Alpha-Cronbach coefficient. Alpha-Cronbach values for individual dimensions were CE (0.778), RC (0.779), and SI (0.801). As can be seen, for

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the measurement scales adopted in this study, Cronbach's alpha coefficients reached high values (above 0.75) for all three dimensions.

In all identified channels of knowledge and technology transfer from universities, one can find activities that can help enterprises operate in a sustainable manner and solve environmental problems. Through consulting and educational channels, scientists can share knowledge on pro-ecological solutions and in the field of cleaner production through consulting, training or developed expert opinions. In turn, the research and commercialisation channel may enable scientists to cooperate and develop patents and licences in the field of new ecological technological solutions for industry. Through the research and information channel, universities and enterprises can create new knowledge about solutions for environmentally friendly industries or disseminate research results.

Discussion

A new element that this article complements the empirical literature is the analysis of a wide range of forms in which scientists from technical universities in Poland can cooperate with enterprises in order to solve environmental problems. The concept of a sustainable university, which emphasises the role of universities in solving global environmental problems through education and research, to a large extent, requires the transfer of knowledge from the area of sustainable development to enterprises.

The research results presented in the article suggest that scientists from Poland engage in 3 forms of knowledge and technology transfer to enterprises, collaborating in the field of education and consulting, research and commercialisation, and science and information. The categories of cooperation shaped in this way may prove the complementarity of educational activities with consulting activities, scientific activities with commercialisation activities, and research activities with information activities of scientists. Some knowledge transfer activities are interdependent and mutually reinforcing (Landry et al., 2007). In the literature, one can find justification for such forms of cooperation, as it is emphasised that there may be complementarity between various activities related to the transfer of knowledge from universities to enterprises. Previous studies, for example, have found complementarity between publishing and patenting (Azoulay et al., 2009), but in the study described in this article, researchers' propensity to publish and patent is not a single construct. However, the complementarity between teaching and consulting noted in the literature (Link et al., 2007) was confirmed in this study. Scientists who more often consult solutions to problems in the industry also more often conduct training for enterprises. The activities within the science and information channel, which turned out to be a construct in this study, seem to be similarly consistent. Scientists who publish in partnership with companies naturally share their research results at conferences organised jointly with industry. Landry et al. (2010) analyse the complementarity of a whole range of knowledge transfer activities, namely publishing, informal knowledge transfer, patenting, spinoff creation and consultancy. In this study, conducted among scientists from technical universities in Poland, it turned out that most often, researchers cooperate with enterprises in an informal way. The largest number of indications on the forms of cooperation concerned informal consultations for enterprises (over 80% of responses), preparation of a report or expert opinion for the enterprise (over 64%) or obtaining information from the enterprise for its own research (over 60% of responses) (Table 4). Thus, it can be noticed that scientists from Poland cooperate with enterprises mainly in an informal way. This is not contradictory, for example, with the research of other foreign authors. In American studies developed by Cohen's team (Cohen et al., 2002), it turned out that informal cooperation mechanisms are also the dominant source of information for business: publications and reports (41.2%) and informal interactions with scientists (35.6%) as well as seminars and conferences (35.1%). Services are listed next: consulting (31.8%) and sponsored research (20.9%). The situation of undertaking informal cooperation in Poland may result for several reasons: the fact that informal cooperation can be more flexible than formal contracts, and the excessive burden of formalities can be avoided (Trzmielak et al., 2016). Additionally, informal collaboration may be more effective in situations where researchers and companies need to respond quickly to changing market or technological conditions, and some projects may be more experimental, making informal collaboration more appropriate.

The efforts of universities to help companies become sustainable will inspire other organisations to embark on the process of becoming sustainable. Scientific research is fundamental to understanding the challenges facing our planet, such as climate change, biodiversity loss and resource depletion. Science influences policy and management decisions by providing evidence-based insights. In turn, governments and organisations, including universities, develop policies to guide activities for sustainable development.

Taking into account several key points related to sustainable cooperation between universities and businesses, a few conclusions can be made regarding the forms of cooperation in which universities and enterprises can cooperate.

1. Sustainable universities can work with businesses to research environmentally friendly technologies, sustainable practices and solutions to

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critical environmental challenges. Companies can provide infrastructure, funds and resources to support research ventures.

2. Internships and Employment: Universities that partner with companies in the field of sustainability may offer students internships, collaborative programs, or job opportunities. This allows students to gain hands-on experience, apply their knowledge and contribute to sustainability projects in real business settings.
3. Joint research projects: joint projects between universities and companies can result in innovative solutions to sustainability problems. These projects may include the development of renewable energy systems, the design of environmentally friendly products or the development of waste reduction strategies. Universities and companies working together can have a positive impact on the local community by implementing sustainable initiatives. This may include organising workshops or information campaigns on environmental protection and responsible business practices.
4. Consulting, training and seminars: universities can share their knowledge on sustainability with companies, providing them with insight into sustainable practices and strategies. In turn, companies can offer insights into industry needs, challenges and potential areas for innovation.
5. Networking: collaborating with companies provides opportunities for students and researchers to network and build connections within the industry. This can lead to partnerships, mentoring and potential career paths for students.
6. Access to infrastructure: companies may provide funding or access to their infrastructure to support sustainable university programs. These resources can help universities expand their teaching, research and outreach activities related to sustainable development. Businesses can benefit from collaborating with sustainable universities, gaining access to new perspectives, cutting-edge research, and a range of qualified alumni who are well-versed in sustainability practices.

Collaboration between sustainable universities and businesses can contribute to broader societal change by promoting sustainable values and practices in the business sector and society in general.

Conclusions

The main aim of the article was to identify the channels through which scientists in Poland transfer knowledge and technology to enterprises. The specific objective was to indicate the forms in which scientists can transfer knowledge and technology to enterprises in the field of sustainable solutions.

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In the theoretical part, the authors reviewed previous research on research in the field of university-enterprise interaction. On this basis, they identified the main dimensions/channels in which interactions may occur. So far, the research, in a comprehensive way, has not identified the various forms by means of which cooperation with enterprises can be developed. Their results were fragmentary, or a limited number of forms of cooperation were explored. The results of the research on the basis of which the author drew conclusions concern a large population of scientists from technical universities in Poland.

The study made it possible to identify the preferred channel of knowledge and technology transfer to industry. Thanks to the use of factor analysis, the main channels/dimensions of viewer transfer in Poland were distinguished.

Referring to the above issues related to the measurement and evaluation of the involvement of scientists in cooperation with enterprises, the research focused on the dimensions of involvement, reflecting various activities that researchers can engage in. Due to the unobservable nature of the involvement, it was assumed that academic commitment reveals a multidimensional structure in five preliminary dimensions, the existence of which is evidenced by their symptoms (reflexive indicators). As a result of factor analyses, three correlated dimensions (constructs) of the assessment of involvement in cooperation were obtained, defined as scientific and informational, consulting and educational, and research and development.

Collaboration between researchers and companies in the area of sustainable solutions may differ from collaboration in other areas for several important reasons. First, the goals of a sustainability project may be more complex and multidimensional than in other fields, which may require an interdisciplinary approach. Secondly, sustainable solutions often require long-term strategies and actions. Third, sustainable solutions often require combining knowledge from different fields, such as natural sciences, social sciences, engineering and economics. Technical universities are places where research is carried out by many researchers from various disciplines, both technical and social, so in such an environment, it is easier to cooperate in interdisciplinary teams on sustainable solutions. Inter-research collaboration and interdisciplinarity are key to creating effective solutions. Moreover, ethics and responsibility play an important role in the implementation of such projects. In general, collaboration between researchers and companies in the area of sustainable solutions can be more complex and require a more comprehensive approach than collaboration in other areas.

The authors are aware of the limitations of research related to the selection of the sample (only a part of the population of scientists from a technical university in Poland were the respondents). Additionally, future research

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should develop a scale to measure the forms of cooperation between the university and industry only in the field of environmental solutions. An interesting approach in future research would be, for example, a comparison of such activities, e.g. between technical universities in the European Union. Another limitation is the choice of factors that determined the latent variable. Although they were selected on the basis of existing literature, they may not take into account all the variables that may be an important channel for collaboration (it was not possible for the respondent to tick their own answer). The conclusions also apply to the research sample in general, without division into the disciplines of researchers. It will also be interesting to analyse the preferences regarding the choice of the channel of cooperation with the company, depending on the researcher's discipline. In addition, an interesting area for in-depth future research will be the role of the academic ecosystem in supporting cooperation between scientists and enterprises. In other words, an interesting approach to research would be to assess the various activities, processes and structures of universities and their impact on the willingness of scientists to engage in cooperation.

Research results provide scientists and policymakers with the information they need to better understand an effective mechanism for sustainable knowledge transfer from university to industry. Overall, the partnership between a sustainable university and businesses creates a synergy where academia and industry work together to address environmental and social challenges while also fostering economic growth and development.

Overall, universities have the potential to lead change towards a more sustainable world and work with businesses to address global sustainability challenges.

A sustainable university that cooperates with businesses typically refers to an educational institution that actively engages with the business sector to promote sustainability initiatives, research, and projects. This collaboration can take various forms and have multiple benefits, including advancing sustainability practices, fostering innovation, and providing students with real-world learning opportunities.

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The contribution of the authors

Conceptualization, U.K. and A.I.D.; literature review, U.K. and A.I.D.; methodology, U.K.; formal analysis, U.K. and A.I.D.; writing, U.K. and A.I.D.; conclusions and discussion, U.K. and A.I.D.

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