Acta Montanistica Slovaca
ISSN 1335-1788
actamont.tuke.sk

The State Of International Technology Transfer In The Northern Europe Region: Comparative Analysis By Modern Multiple Criteria Methods

*Giedrė LAPINSKIENĖ[1], Askoldas PODVIEZKO[2] and Manuela TVARONAVIČIENĖ[3]**

Authors' affiliations and addresses:
[1] Department of Business Technologies and Entrepreneurship, Vilnius Gediminas Technical University (VILNIUS TECH), Sauletekio 11, LT-10223 Vilnius, Lithuania
[1] Faculty of Economics, VIKO Higher Education Institution, Saltoniškių 58, LT-08105 Vilnius, Lithuania
e-mail: giedre.lapinskiene@vilniustech.lt

[2] European Humanities University, Savičiaus 17, LT-01127 Vilnius, Lithuania
[2] Mykolas Romeris University, Ateities 20, LT-08303 Vilnius, Lithuania
e-mail: askoldas.podviezko@ehu.lt

[3]*Correspondence:
Manuela Tvaronavičienė, Department of Business Technologies and Entrepreneurship, Vilnius Gediminas Technical University (VILNIUS TECH), Sauletekio 11, LT-10223 Vilnius, Lithuania
tel.: 37068783944
e-mail: manuela.tvaronaviciene@vilniustech.lt

Funding information:
Funding Agency: Iceland, Liechtenstein and Norway through the EEA Grants. Project Title: The Economic Integration of The Nordic-Baltic Region Through Labor, Innovation, Investments and Trade (LIFT)
Grant Number: Project contract with the Research Council of Lithuania (LMTLT) No is S-BMT-21-7 (LT08-2-LMT-K-01-070)

How to cite this article:
Lapinskienė, G., Podviezko, A. and Tvaronavičienė, M. (2023). The State of International Technology Transfer in The Northern Europe Region: Comparative Analysis by Modern Multiple Criteria Methods. *Acta Montanistica Slovaca,* Volume 28 (1), 69-82

DOI:
https://doi.org/10.46544/AMS.v28i1.07

Abstract

The undiminished importance of international technology transfer (ITT) consistently attracts attention from scientists, businesses, and governments. The OECD acknowledges the benefits of the ITT and emphasises that European countries should be open to new opportunities that ITT brings in each economic sector, from primary to tertiary. The mining sector does not represent an exception. ITT contributes to job creation and growth worldwide by creating new markets and expanding existing ones. ITT transforms human fifes and surrounding very quickly. The TT improves production efficiency, stimulates growth; reformats patterns of sectors; brings new opportunities to every capital owner, and improves economic well-being among people worldwide. At the same time, it changes the value system and, in many cases, seriously harms the environment. Despite the researchers' focus on ITT, more complex research still needs to assess the factors of such phenomena. The article contributes to creating a more comprehensive methodology for evaluating the ITT environment not only in the mining sector but also in the other field of the primary sector. For analysis, the authors use popular Multiple Criteria Decision Aid (MCDA) methods and develop objective methods for criteria weights calculation. The study evaluates and compares internal conditions for OECD Northern Europe countries to implement, develop and share technologies. For this purpose, a set of 16 quantitative criteria was created; their hierarchical structure with four categories was set. A detailed comparative analysis of the state of the countries in terms of favourable conditions for the ITT was performed.

Keywords

international technology transfer; multiple criteria evaluation; factors

Introduction

Technology and innovation are critical determinants of long-term per capita productivity and income growth. International technology transfer (ITT) whereby one country's organisation assesses another organisation's capital and knowledge to enhance production. International trade and foreign direct investment are two virtual channels behind human migration, and mergers and acquisitions of ITT and all-related policies and factors are critical elements of the national technology and innovation strategies in all the economic sectors from the beginning in the mining sector through the processing of materials in the secondary sector to the services in the tertiary sector.

The history of analysis of ITT phenomena started approximately in 1960, and since then, reviewed the literature on ITT showed three broad directions of studies: macro, mezzo and micro. Articles from a macroeconomic standpoint exploded factors impacting ITT (Derakhshani, 1983; Madu, 1989) and drivers of the effectiveness of TT (Bozeman etc., 2015). Mezzo analysis covered the large stream of articles analysing the role, performance and process in creating a smooth link between inventors and organisations of universities and research agencies (Good et al., 2019; Matthew et al., 2019; Steruska et al., 2019).

Micro-economic approach studies analyse particular aspects of ITT processes, e.g., value-added supply chains and organisational learning) (Burinskas et al., 2021, Radavičius & Tvaronavičienė, 2022; Holubčík et al., 2022; Laužikas et al., 2022; Khorshid et al., 2023). Such blocks of studies can be visualised as triangular among government performance, universities and organisations. The global threat of climate change and other environmental degradation and the rapid development of countries encourage deepening the studies of favourable ecological conditions for stimulating ITT processes where the state's role has ceased to be necessary.

The primary notion is that developing countries can effectively promote economic growth by creating a favourable environment for technology transfer. As the ITT considerably impacts society's welfare, it became essential to compare countries in terms of their attractiveness of developing ITT processes. Analysis of factors that influence the environment for the ITT in the literature usually consists of the following aspects: economic development (Derakhshani,1983; Madu, 1989; Bozeman et al., 2015; Shouwu et al., 2016; Noh and Lee, 2019; Jiaoe et al., 2021); government support and regulation Derakhshani, 1983; Shouwu et al., 2016; Kowalski et al., 2017; Jiaoe et al., 2021), political system (Derakhshani, 1983; Madu, 1989; Bozeman et al., 2015; Shouwu et al., 2016; OECD, 2017); social-cultural value (Derakhshani, 1983; Madu, 1989; Bozeman et al., 2015; Shouwu et al., 2016); market size Bozeman et al., 2015; Shouwu et al., 2016); characteristics of organisations (Derakhshani 1983; Shouwu et al., 2016); R&D (Madu, 1989; Bozeman et al., 2015; Shouwu et al., 2016; Kučera & Fiľa, (2022). However, these measures have national technology upgrading as their primary policy objective. Those measures that can significantly impact international competition have yet to be identified (Kowalski et al., 2017).

This paper aims to compare conditions for the ITT in ten countries of the region of Northern Europe by employing some tools of the multiple criteria analysis and to obtain the evaluation result in a convenient form that enables observing the situation in the region. The result is provided by the ranking of the countries, which compares their favorability. In addition to the ranking, the analysis depicts factors that must be addressed in each country, even in the most prominent ones.

The methodology requires choosing criteria that describe conditions for the ITT in a country, and the paper presents grounding for the selected criteria. A hierarchy structure of 16 criteria comprising four categories was set for all the economic sectors, including mining. Two of the most popular multiple criteria decision-making methods (MCDM), SAW (Simple Additive Weighing) and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), were chosen. The objective method of estimating weights in accordance with proportional differences (APROD) was proposed and used along with another accurate entropy method to increase precision. The obtained results were tested for inconsistencies.

The results of the comparative evaluation will be of interest to researchers of the ITT as well as to developers of the objective methods of estimating criteria weights.

Literature review

The dictionaries explain technology as methods, systems, and devices resulting from scientific knowledge being used for practical purposes and scientific knowledge used in practical ways in the industry (The Oxford English Dictionary, Collins-dictionary). According to Dorf and Worthington (1987), technology has been described as the engine of progress, wealth creation, and, therefore, economic growth since the first Industrial Revolution Technology is the complex element of knowledge impacting the transformation of life and surroundings, especially in our in a technological society (Maskus, 2004). Earlier definitions commonly presented technology as a fixed, stable, and tangible thing; nowadays, the technology is not permanently designated, and it will undergo changes to suit where it is being used (Oti-Sarpong & Leiringer, 2021). Technology does not create wealth. Rather, it is the products and services generated due to the application of technological inventions or innovations through commercialisation that create wealth. According to Kowalski et al. (2017), the most valuable aspects of tradable technology are patentability, patent search completed and clean, literature search completed and clean, confidentiality maintained and no pending publications and the existence of a functioning. In the sustainability context, some organisations already assess the technological depth and impact on the area, whether benefits will outweigh limitations, whether there were multiple fields of use, and whether there were any safety, environmental, governmental, or public acceptability barriers. The article supports the definition of technologies as the term descends from scientific invention; it is understood as a means used in human activity (especially in industries) to help humans enhance their lives and environment. Hence, the main features of modern technology are the classification of technologies; propensity to make a profit; flexibility – to fit the industry or place; patentability - intellectual property rights play an essential role in technology trade; assessment of environmental impact.

The concept of technology transfer is age-old and has been rightly referred to as a fundamental process that influences the economic performance of nations and firms, enhancing globalisation. The concept is, therefore, broad. Since before the Industrial Revolution, countries at the technological periphery have attempted to obtain technology from those at the frontier. The United Nations Draft Code of Conduct on the Transfer of Technology defines technology transfer as "the transfer of systematic knowledge for the manufacture of a product, for the application of a process or the rendering of a service and does not extend to the transactions involving the mere sale or mere lease of goods" (UNCTAD, 2014). WIPO (2011) defines technology transfer as a series of processes for sharing ideas, knowledge, technology and skills with another individual or institution (for instance, a company, a university or a governmental body) and of acquisition by the other of such ideas, knowledge, technologies and skills. Technology transfer (TT) is any process by which one party gains access to a second party's information and successfully learns and absorbs it into his production function (Maskus, 2004; Kowalski et al., 2017). TT process is critical in transferring environmentally friendly technologies around the world. TT is a vital tenet of the 1992 United Nations Framework Convention on Climate Change to "promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases not regulated by the Montreal Protocol in all relevant sectors including mining (1992 United Nations Framework Convention on Climate Change). However, the analysis of Liu et al. (2022) demonstrated that technology transfers are complex processes, and their outcomes may be challenging to predict. There is a need for caution, as the effects of technology transfer in society depend entirely on how technologies become locally rooted (Liu et al., 2022; Palaco et al., 2022). Puig et al. (2018) state that TT should reflect national priorities and concerns. Hence, technology transfer refers to the processes by which one economic agent gains access to a second party's technology and related knowledge, successfully learning and absorbing both into his production function. Summarised literature leads to the main elements of TT: various stages that require investment, time and effort; can be classified as vertical and horizontal; active and passive; commercial and non-commercial; motivation and experience of transferor and transferee are fundamental; the importance of cooperation as well as reflects national priorities and concerns.

In the mid-1960s, technology transfer was first mentioned in international economic and technological theories. It has been widely defined as the flow of tangible knowledge (products, equipment, parts, etc.), intangible knowledge (proprietary technologies, patents, technical standards, technology licenses), and macro and micro information of countries, regions, enterprises, organisations, and individuals (Jiaoe et al., 2021). One of the first definitions of ITT widely cited is dedicated to Derakhshani, where International technology transfer is the acquisition, development, and utilisation of technological knowledge by a country other than that in which this knowledge originated (Madu, 1989). ITT, whereby a party from one country gains access to a foreign party's information and successfully learns and absorbs it into his production function (Maskus, 2004). Research suggests that the common goal was to understand the technology transfer phenomena from a macroeconomic standpoint (Madu, 1989; Roszkowska, 2013; Cimoli et al., 2019; Noh & Lee, 2019). The previous work has lent credence to technology transfer and provides (Bozeman et al., 2015; Noh & Lee, 2019) a holistic view of the field and have come close to the type of ITT relevant to our interests. Although cases of technology transfer that have transcended national boundaries are reported as ITT, these cases have often looked at the flow from within a sole interregional organisation (i.e. from within a multinational firm to its foreign subsidiary, through merger and acquisition, or even foreign-direct investments) (Rigo, 2020).

Hence, ITT refers to the processes by which one economic agent gains access to technology and related knowledge from another country and successfully learns and absorbs both into his production function. According to Hall (2022) and Kwadwo and Leiringer (2021), international technology transfer typically occurs via trade, foreign direct investment, joint ventures with local partners, or simple technology licensing and projects. However, some tacit knowledge must also be transferred in the latter case. Licensing is one of the major channels for promoting TT, creating income for the patentee and promoting the dissemination and further development of technologies by a wider group of licensees (WIPO, 2010 OECD). However, access to technology is also available via free-of-charge research publications, patent application forms, migration of scientists and engineers, or their participation in workshops, seminars, trade fairs, and the like. Nonetheless, stores of knowledge accessible in such forms are usually insufficient to implement on a market scale.

Many cases of ITT studies described the flow of technology located in different geographical locations surrounded by asymmetric environmental conditions and peculiarities of a particular industry (Derakhshani, 1983: Madu, 1989). According to Derakhshani (1983), the factors affecting success were grouped into the environmental characteristics of the recipient and the supplier, the mechanism for technology transfer, and the technology itself. Environmental characteristics of supplier and recipient are market size; absence of factor price distortions in recipient country; good infrastructure; similarity of environments in terms of skills, factor prices, endowments etc.; recipient countries' technological level; culture and social value system; mobility; working traditions and habits; government support and regulations, organisation structure, size and experience of the recipient. The results of Derakhshani's regression analysis stressed the importance of suppliers' motivation, experience and recipient motivation, and government support (1983). Madu (1989) identified eight significant factors, i.e. cultural value system, education and training, capabilities, research and development, identification and implementation of appropriate technology, stable government and political systems, managerial effectiveness, and objectives that lead to the successful transfer of technology. Overall, the significant factors often cited in previous studies mainly focused on three aspects: technology type, political and cultural environments in transferee countries, and gaps between transferor and transferee countries' development level; the relations between a supplier and a recipient as well as level of motivation and experience of a recipient. In early summarising studies, Noh and Lee (2019) mentioned that the ITT's main drivers are open economic policies, trade liberalisation, technical advances in transport and communication, and foreign direct investment.

Bozeman etc. (2015) performed the theoretical model of the effectiveness of ITT based on categorised studies according to their approaches to measuring the effectiveness of ITT in all the economic sectors with no exception of mining. For the effective process, such criteria as level of economic development; favourable political environment; commercial success at the market; level of the development of scientific and technical human capital; public value (which can be referred to as the mission of federal laboratories); reached benefit (income from licenses, broader social and economic impacts) as well as the effectiveness of scientific workers. This study is very close to what we are doing – evaluating the cross-national effectiveness of ITT.

Shouwu et al. (2016) used the Interpretative Structural Model Method to test twenty factors impacting ITT, presented in the Hierarchical structure at the three levels – basic, actionable and surface layers. The level of economic development is the most fundamental reason for following industrial structure. Infrastructure construction, technical gap, economic openness, international economic environment change, technological progress complexity, the uncertainty of market incompleteness, technology life cycle and cultural tradition are basic layers. Actionable factors are technical application, negotiability, technical transfer intermediary, acceptance ability of international technology, international companies, laws and acts, and the level of marketing competition are acting path layers. Technical transfer type, human resources, suppliers' output willingness and ability, and government strategy and policy are surface-layer direct factors.

Kowalski et al. (2017) analysed technology transfer-related policies grouped into six categories: absorptive capacity policies; measures related to intellectual property rights (IPR); FDI promotion measures; FDI restrictions and screening; performance requirements; and investment incentives. Absorptive capacity policies are usually horizontal domestic policies related to education and workforce training, educational and scientific institutions and their links with business, the business climate and access to finance. IPR protection, including relevant provisions on patent and licensing agreements, trade secrets, test data and IPR-related provisions in competition law, plays a significant role in creating the necessary market conditions for ITT (Lazaroiu et al., 2022). It is thus a prerequisite for ITT. Most countries have FDI investment promotion and restrictions policies and screening which target technology-related investment in specific sectors, but only some countries have sector or technology-specific administrative simplifications. According to the paper, technology transfer-related performance requirements are common in developed countries. However, they still seem relatively familiar in developing countries, especially regarding sectoral, local content requirements in government procurement, local employee quotas, and provisions for training requirements and substituting foreign with national employees. Some performance requirements have been disciplined in international agreements such as the WTO TRIMS and related provisions in BITs and PTAs.

The patent protection system has been mentioned by Bronwyn (2022) as an essential factor for transferor and transferee countries. In other words, these patents positively influence European countries' economic growth. However, this study could not verify environmental patents' positive impact on economic development within the Eurozone (Ferreira et al., 2020).

The degree of success of technology transfer is believed to be a function of at least four variables - levels of literacy, public policy, ideology and cultural values and the degree of competition for the use of resources (Moikangoa, 2000; Androniceanu et al., 2021; Androniceanu et al., 2022).

According to Jiaoe et al. (2021), the effect of technology transfer is influenced by different factors, such as the type of technology and the differences between the transfer subjects in institutional and cultural environments. Institution factors can cover main criteria such as the political system and stability level, security of law, corruption level, and cultural elements can be divided into the level of industrialisation and values system.

According to OECD, policies directly setting limits to ITT are rare and often determined by other considerations, such as, for example, those related to antitrust and national security (2017). Both countries benefit from ITT, but the national security factor should also be carefully considered between partner countries. Menaldo & Wittstock (2021) provided the study between US and China; despite massive benefits for both countries, there are some sensitive industries like American technology related to radar and quantum computing.

In ITT analysis, sectoral specificities are very important (notably in the natural resource sectors Menaldo & Wittstock (2021). Authors often analysed a particular industry: railway construction projects (Jiaoe, 2021; Roberts & Hauptman, 1986).

The complexity of the criteria stems from the fact that favourable conditions for international technology transfer include multiple dimensions of primarily four vectors; thus, criteria were grouped into four following categories, which were derived from the literature: Economic, Political and Legal, Promotion and Screening of R & D, Social (absorptive capacity). At the next step of choosing precise quantitative criteria, the authors paid particular attention to the validity and quality of quantitative data and the underlying logic beneath the nature of each criterion.

The Economic category comprises the magnitude of imports and exports related to international technology transfer, namely FDI and high-tech. Databases Eurostat and OECD are reliable and do not cause any doubts about providing insufficient quality data.

The Political-legal category emphasises the intensiveness of regulation, both of restrictive and business-supportive nature, along with such a criterion as trust in government. Such a category exposes the freedom to create technology ideas within a country and share and implement them abroad.

The character of the category Promotion and screening of R&D is self-explanatory. It includes the Knoema index (Knoema, 2023) of University-industry collaboration in R&D and the number of international patent applications made following The Patent Cooperation Treaty (PCT).

The Social (absorptive capacity) category was included to reveal the creative potential of a society. The first three criteria emphasise fundamental sciences, while the last criterion reflects the overall educative level of the society in question.

***Table 1**. List of criteria that are ambient to the ITT*

Category	Name of criterion	Description	Database
Economic	1. High-tech exports	Exports of high technology products as a share of total exports	https://ec.europa.eu/eurostat/data/database
	2. FDI stocks exports	Outward, % of GDP	https://stats.oecd.org/
	3. FDI stocks imports	Inward, % of GDP	https://stats.oecd.org/
Political-legal	4. Trade Regulation	Services Trade Restrictiveness Index	https://stats.oecd.org/
	5. FDI regulation	FDI Regulatory Restrictiveness Index	https://stats.oecd.org/
	6. Legal enforcement of contracts	The time and money required to collect a debt	https://www.fraserinstitute.org/sites/default/files/economic-freedom-of-the-world-2022-dataset-by-country-tables.xlsx
	7. Capital controls	Percentage of capital controls not levied	https://www.fraserinstitute.org/sites/default/files/economic-freedom-of-the-world-2022-dataset-by-country-tables.xlsx
	8. Intellectual property payments	% of total transactions	https://knoema.com/infographics/aomssce
	9. Degree of trust in government	The share of people who report having confidence in the national government	https://stats.oecd.org/
	10. Protection of property rights	Index	https://www.fraserinstitute.org/sites/default/files/economic-freedom-of-the-world-2022-dataset-by-country-tables.xlsx
Promotion and screening of R&D	11. University-industry collaboration in R&D	Index	https://knoema.com/infographics/aomssce
	12. PCT applications	Number of applications per 100 billion GDP	https://knoema.com/infographics/aomssce
Social (absorptive capacity)	13. Tertiary graduates from STEM programmes	Index	https://knoema.com/infographics/aomssce
	14. Proportion of citizens with basic digital skills	Percentage of individuals aged 25 to 64 with high formal education that has basic digital skills	https://ec.europa.eu/eurostat/data/database
	15. Proportion of ICT specialists	Proportion of ICT specialists in total employment	https://ec.europa.eu/eurostat/data/database
	16. Enrolment of master's, doctoral or equivalent	Index that reflects the proportion of master's, doctoral or equivalent in the total number of students	https://knoema.com/infographics/aomssce

A system of theoretically grounded selected indicators, which will be used for further research, is provided above (see Table 1).

Material and Methods

Principles of evaluation and data

Comparison of countries within a region provides specific insight into lagging and prominent conditions. It is expected to enhance monitoring of the environment that provides ambience for successful technology transfer. There is no evidence that better conditions imply a more rapid technology transfer. Still, it is a permanent concern of governments to provide such conditions along with the promotion of valuable human activity to ensure future growth and education depth and variety, both cultural and multidisciplinary, of the countries.

Researchers chose the region of their residence, namely OECD Northern Europe. It comprises the following ten countries selected for the study: Denmark, Estonia, Finland, Iceland, Ireland, Latvia, Lithuania, Norway, Sweden, and the United Kingdom. The region has some prevailing characteristics, such as a harsh climate; a relatively high level of income per capita; a propensity for education and R&D, and belonging to or having a close relationship with the EU. Many close relationships among these countries formed historically, e.g. the Baltic region. There are also some exceptional connection cases; for instance, Norway, Sweden, Finland, Denmark and Iceland have achieved grid interconnection, forming a unified Nordic electricity market (Nord Pool) (Zhao et al., 2023).

Multiple criteria analysis methods fit exceptionally well when there are few alternatives to be compared and some, even vague, evaluation purpose is stated (Roy, 2005; Dobrovolskienė & Pozniak, 2021). The more complex the purpose of evaluating, the better the multiple criteria evaluation paradigm fits as the methods successfully deal with mutually conflicting, multi-dimensional evaluation criteria. In our case, we deal with a rather vague term as favourable ambience for technology transfer in a country. The criteria selection process makes the evaluation purpose more concrete as the criteria list is filled. To make the process smoother, broader criteria categories should be cast, usually with the help of the literature. Then, each class is gradually filled with criteria found in major international databases (Table 1), paying attention to data availability.

Gleaned from the stated in the latter table, databases values of criteria r_{ij} are placed into the decision matrix $\|r_{ij}\|$, where the index i of entries denotes the criteria while index j denotes evaluated alternatives, as is presented in Table 2.

***Table 2**. Decision matrix with values of criteria*

	Dimension	Denmark	Estonia	Finland	Iceland	Ireland	Latvia	Lithuania	Norway	Sweden	United Kingdom
1	% (no dimension)	13.67	19.35	10.29	33.49	25.66	16.96	11.51	20.75	13.94	23.85
2	% (no dimension)	35.82	90.53	27.99	30.56	276.48	61.85	46.88	35.60	56.53	81.99
3	Index (no dimension)	68.76	32.64	54.50	20.24	291.35	15.48	17.55	44.71	68.61	67.85
4	Index (no dimension)	0.19	0.22	0.23	0.37	0.18	0.17	0.19	0.27	0.22	0.16
5	Index (no dimension)	0.06	0.02	0.03	0.17	0.03	0.02	0.02	0.11	0.08	0.04
6	Index (no dimension)	6.57	5.98	6.29	6.78	4.72	5.53	6.24	7.30	6.11	6.07
7	Index (no dimension)	6.92	5.38	3.08	1.54	7.69	6.92	6.92	4.62	3.08	4.62
8	% (no dimension)	79.80	70.20	93.30	79.30	48.50	60.20	62.10	85.50	87.40	48.00
9	Index (no dimension)	69.10	47.60	75.80	59.10	67.30	49.50	53.40	61.70	71.00	69.00
10	% (no dimension)	41.60	51.60	52.40	37.30	46.80	36.80	31.90	38.70	50.50	48.50
11	% (no dimension)	22.20	6.50	28.00	23.70	100.00	3.80	4.90	14.20	98.40	49.10
12	Ratio	91.80	76.90	94.90	85.10	80.40	67.70	64.40	82.60	97.60	82.90
13	ratio (no dimension)	60.20	51.88	68.88	69.75	61.09	53.10	52.37	63.32	59.78	60.04
14	Index (no dimension)	65.17	51.93	71.37	63.39	62.34	29.46	30.38	77.35	63.35	39.48

The sequence of dealing with the data is outlined as follows.

Normalisation of data

The data is taken from different databases and represents various aspects of the state of each country. It has a multi-dimensional character and, thus, cannot be comprised into a single criterion of evaluation of a method of multiple evaluations without a normalisation procedure. While no normalisation tool exists in the TOPSIS method, there is a particular choice of normalisation formula or even formulae for each criterion (Podviezko, 2014). The normalisation formula for the TOPSIS method is as follows:

$$\tilde{r}_{ij} = \frac{r_{ij}}{\sqrt{\sum_{j=1}^{n} r_{ij}^2}} \quad (1)$$

where r_{ij} are values taken from the decision matrix; $\tilde{r}_{ij}$ are normalised values; index i denotes the criteria, while index j denotes the alternatives.

The choice of the following formula was based on the fact that the worst value of each criterion is mapped to zero. In contrast, the best value is mapped to the unity, while values between the extremes are mapped linearly into the named interval [0,1].

$$\tilde{r}_{ij} = \frac{r_{ij} - \min_j r_{ij}}{\max_j r_{ij} - \min_j r_{ij}} \cdot 100\% \quad (2)$$

where r_{ij} are values taken from the decision matrix; $\tilde{r}_{ij}$ are normalised values; index i denotes the criteria, and index j denotes alternatives under evaluation.

This feature will be used for combining normalised values with objective weights obtained by the newly proposed method APROD (weights in accordance with proportional differences) of deriving weights from the data structure. Objective methods of estimating weights are popular among scientists, such as IDOCRIW, and CILOS (Zavadskas & Podvezko, 2016), while subjective methods are also popular (Kurschus et al., 2019) for example. In addition, such normalisation maps values of each criterion linearly to the interval [0,1], which allows to analyse and compare countries by each criterion separately, thus making the analysis more detailed (Podviezko, 2012). Normalised values are presented in Table 3 and Table 4 for each method separately.

***Table 3.** Normalised values for the SAW method*

	Denmark	Estonia	Finland	Iceland	Ireland	Latvia	Lithuania	Norway	Sweden	United Kingdom
1	14.55	39.07	0.00	100.00	66.27	28.73	5.24	45.08	15.72	58.46
2	3.15	25.17	0.00	1.04	100.00	13.63	7.60	3.06	11.49	21.73
3	19.31	6.22	14.14	1.72	100.00	0.00	0.75	10.59	19.26	18.98
4	83.62	70.66	65.31	0.00	88.59	96.97	85.59	47.23	70.58	100.00
5	73.86	98.78	95.08	0.00	90.92	100.00	97.81	39.77	61.41	87.40
6	28.29	51.16	39.15	20.16	100.00	68.60	41.09	0.00	46.12	47.67
7	12.52	37.56	74.96	100.00	0.00	12.52	12.52	49.92	74.96	49.92
8	70.20	49.01	100.00	69.09	1.10	26.93	31.13	82.78	86.98	0.00
9	76.24	0.00	100.00	40.78	69.86	6.74	20.57	50.00	82.98	75.89
10	47.32	96.10	100.00	26.34	72.68	23.90	0.00	33.17	90.73	80.98
11	19.13	2.81	25.16	20.69	100.00	0.00	1.14	10.81	98.34	47.09
12	82.53	37.65	91.87	62.35	48.19	9.94	0.00	54.82	100.00	55.72
13	46.54	0.00	95.13	100.00	51.56	6.79	2.74	64.00	44.19	45.66
14	74.57	46.91	87.52	70.84	68.65	0.00	1.93	100.00	70.77	20.91
15	42.86	57.14	59.52	0.00	0.00	85.71	100.00	4.76	38.10	42.86
16	68.04	37.97	100.00	63.92	54.11	0.00	0.63	55.38	43.04	41.46

***Table 4.** Normalised values for the TOPSIS method*

	Denmark	Estonia	Finland	Iceland	Ireland	Latvia	Lithuania	Norway	Sweden	United Kingdom
1	0.21	0.30	0.16	0.53	0.40	0.27	0.18	0.33	0.22	0.37
2	0.11	0.28	0.09	0.09	0.85	0.19	0.14	0.11	0.17	0.25
3	0.21	0.10	0.17	0.06	0.90	0.05	0.05	0.14	0.21	0.21
4	0.27	0.31	0.32	0.51	0.25	0.23	0.26	0.37	0.31	0.22
5	0.25	0.09	0.12	0.72	0.14	0.09	0.10	0.47	0.33	0.17

6	0.34	0.31	0.32	0.35	0.24	0.28	0.32	0.37	0.31	0.31
7	0.40	0.31	0.18	0.09	0.45	0.40	0.40	0.27	0.18	0.27
8	0.35	0.30	0.40	0.34	0.21	0.26	0.27	0.37	0.38	0.21
9	0.35	0.24	0.38	0.30	0.34	0.25	0.27	0.31	0.36	0.35
10	0.30	0.37	0.38	0.27	0.34	0.26	0.23	0.28	0.36	0.35
11	0.14	0.04	0.18	0.15	0.64	0.02	0.03	0.09	0.63	0.32
12	0.35	0.29	0.36	0.32	0.31	0.26	0.25	0.31	0.37	0.32
13	0.32	0.27	0.36	0.37	0.32	0.28	0.27	0.33	0.31	0.31
14	0.36	0.28	0.39	0.35	0.34	0.16	0.17	0.42	0.35	0.22
15	0.31	0.34	0.34	0.21	0.21	0.41	0.44	0.22	0.30	0.31
16	0.34	0.30	0.38	0.34	0.32	0.25	0.25	0.33	0.31	0.31

After multiplying with weights specified below, hypothetic best and worst alternatives are found as presented in Table 5, as is required in the TOPSIS method.

***Table 5.** Hypothetic best and worst alternatives for the TOPSIS method*

	BEST alternative (APROD)	WORST alternative (APROD)	BEST alternative (entropy)	WORST alternative (entropy)
1	0.038	0.012	0.030	0.009
2	0.094	0.010	0.072	0.007
3	0.109	0.006	0.087	0.005
4	0.012	0.028	0.012	0.028
5	0.009	0.077	0.007	0.057
6	0.007	0.011	0.012	0.019
7	0.008	0.040	0.005	0.027
8	0.018	0.009	0.021	0.011
9	0.012	0.007	0.020	0.012
10	0.012	0.008	0.019	0.012
11	0.081	0.003	0.063	0.002
12	0.010	0.007	0.019	0.013
13	0.007	0.005	0.019	0.014
14	0.026	0.010	0.023	0.009
15	0.021	0.010	0.024	0.011
16	0.011	0.007	0.020	0.013

Method of deriving weights APROD

It was described in (Podviezko, 2014) that normalisation (2) maps values of each criterion to the interval [0,1], irrespectively how different values are, whether they are close to each other or are much more disbursed. Therefore, even if equal weights were used in the SAW method's formula for the cumulative criterion, extreme criteria values would be adequately accounted for concerning each criterion's initial dispersion of values. In other words, extreme, best and worst values of criteria derived from sets with small and large dispersion would affect the ultimate result the same way after the transformation. Logically, criteria values with more significant dispersion should affect the comparative evaluation results more than t'ose with lower dispersion. Take an extreme example. Suppose the GDP per person differs by one dollar in two countries of the set's largest and lowest GDP per person. The normalisation would map such values to namely zero and unity. In the case weights would not mitigate such mapping to the extreme edges of the normalisation interval, such a slight difference in original values of the criterion would affect the result rather sharply, which is far from logical.

The method APROD provides a possibility to account for transformed values of criteria with underlying more significant dispersion by attaching larger weights compared to the weights for the values with underlying smaller dispersion. Relative differences between extremes W_i for each criterion i is measured between extreme values in per cent, taking the base as the middle point, as contrast is measured in optics.

$$W_i = 200 * \frac{\max_j r_{ij} - \min_j r_{ij}}{\max_j r_{ij} + \min_j r_{ij}} \tag{3}$$

with the same notations as in (2).

Then, having all such relative differences between extremes found, they are normalised for achieving the requirement that the sum of weights equals the unity by dividing each relative difference by the sum of all such differences, thus finding weights α_i:

$$\alpha_i = \frac{W_i}{\sum_{i=1}^{n} W_i} \tag{4}$$

Entropy method of deriving weights

Entropy is another method of deriving weights from the data that reflects uncertainty within the data or the degree of information that data carries, namely Shannon entropy. In contrast to the previous method, the entropy method uses data for all alternatives (Zavadskas & Podvezko, 2016). This needs to be more clearly learned which measurement is better. Therefore, a comparison of outcomes is intended further in the paper, and the average of the results to mitigate the risks related to each objective method of deriving weights.

The degree of Shannon entropy is measured for each criterion i as follows:

$$H_i = -\frac{1}{n}\sum_{j=1}^{n} \tilde{r}_{ij} \cdot ln\, \tilde{r}_{ij} \tag{5}$$

where $\tilde{r}_{ij}$ are normalised values of criteria for each alternative j. But in this case normalisation formula is different to (3) and reads now as follows:

$$\tilde{r}_{ij} = \frac{r_{ij}}{\sum_{j=1}^{m} r_{ij}} \tag{6}$$

where $\tilde{r}_{ij}$ are normalised values of criterion i, for each alternative j.

It was proved that values H_i are within the interval [0,1]. Degrees of variation d_i later used for estimating weights are obtained by subtracting H_i from one. For each i

$d_i = 1 - H_i$

Weights are obtained by normalising degrees of variation by using the same formula (6). The resulting weights are shown in Table 6.

Weights derived using the standard deviation

The third objective approach of obtaining weights is used in the paper only for reference purposes of analysing the resulting weights. It uses a similar idea as was used in the APROD. Still, it is based on the standard deviation of normalised values of each criterion rather than on the difference between the maximal and minimal value of a criterion. The use of an overall spread of the data incorporated with the normalised values of criteria that are mapped into the interval [0,1] by formula (3) embraces the fact that the magnitude of differences of values of criteria must correspond to the importance of their influence on the result that is carried by weights. Obtained standard deviations are then normalised using the formula (6) to make their sum equal to one. Such a brief description of this simple method is sufficient. This approach is presented solely for reference purposes to graphically reveal the standard deviation in each criterion's set of normalised values together with weights obtained by the other two methods.

The resulting weights are shown in Table 6.

Table 6. *Resulting weights*

Categories	**Economic**			**Political-legal**							**Promotion and screening of R & D**		**Social (absorptive capacity)**			
No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	High-tech exports	FDI stocks exports	FDI stocks imports	Trade Regulation	FDI regulation	Legal enforcement of contracts	Capital controls	Intellectual property payments	Degree of trust in government	Protection of property rights	University-industry collaboration in R&D	PCT applications	Tertiary graduates from STEM programmes	Proportion of citizens with basic digital skills	Proportion of ICT specialists	Enrolment of master's, doctoral or equivalent
APROD weights	0.072	0.110	0.122	0.054	0.106	0.029	0.090	0.125	0.061	0.028	0.031	0.028	0.033	0.020	0.048	0.043
Entropy weights	0.057	0.084	0.097	0.054	0.079	0.051	0.059	0.098	0.055	0.051	0.052	0.051	0.052	0.051	0.054	0.053
Standard deviation (benchmark)	0.057	0.148	0.177	0.042	0.124	0.017	0.060	0.034	0.023	0.025	0.154	0.020	0.016	0.045	0.038	0.018

We draw your attention to Fig. 1 for the visual comparison of obtained weights by different methods.

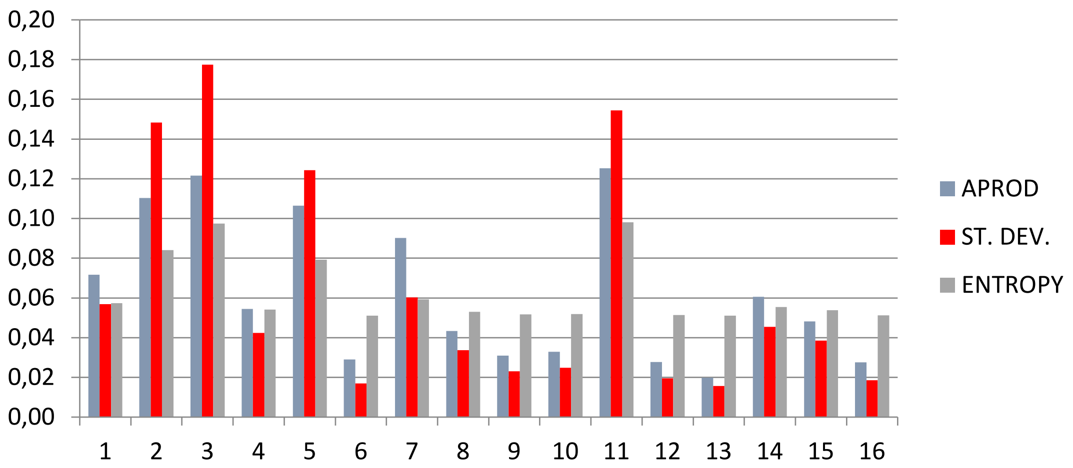

Fig. 1. Visual comparison of obtained weights

Even if the initial visual comparison of the weights obtained using different methods reveals that the most extreme differences exist among normalised standard deviations, the case should not be generalised. Such an "upstart" only shows that data normalisation dramatically changes the situation and introduces distortions (Podviezko, 2014). Of course, non-normalised data affects the alternatives; therefore other two methods are preferable for determining weights.

Less extreme values are obtained using the APROD method, while the most uniform ones are obtained using the entropy. The standard deviation within the sets of weights confirms the latter observation; they are 0.036 for the APROD method, 0.016 for entropy, and 0.054 for the normalised standard deviations within the values of each criterion. Such differences suggest that at least two ways should be used to estimate weights by an objective method, similar to Palevicius et al. (2018). Zavadskas and Podvezko (2016) suggested mitigating risks associated with each method. The approach of performing evaluation using the two sets of weights separately and combining such assessment by taking the average was chosen in this paper.

Results of the MCDA evaluation

As the weights were obtained by two methods that differ by the intrinsic logic, we evaluated the ten countries in question using both sets of weights separately. We omit the description of the chosen methods SAW and TOPSIS, as they could be found in a large number of papers in the realm of the MCDA evaluation. For a better comparison of the results, values of the cumulative criteria of the SAW and TOPSIS methods were normalised by dividing by the sum. The results of the evaluation can be observed in Table 7.

Table 7. *Results of the MCDA evaluation with normalised values of cumulative criteria the SAW and TOPSIS methods*

	Denmark	Estonia	Finland	Iceland	Ireland	Latvia	Lithuania	Norway	Sweden	United Kingdom
SAW criterion (APROD)	0.104	0.093	0.109	0.058	0.180	0.082	0.074	0.078	0.116	0.107
SAW evaluation (APROD)	5	6	3	10	1	7	9	8	2	4
SAW criterion (entropy)	0.107	0.089	0.125	0.070	0.163	0.073	0.064	0.082	0.121	0.106
SAW evaluation (entropy)	4	6	2	9	1	8	10	7	3	5
TOPSIS criterion (APROD)	0.086	0.092	0.090	0.044	0.237	0.089	0.086	0.057	0.114	0.106
TOPSIS evaluation (APROD)	8	4	5	10	1	6	7	9	2	3
TOPSIS criterion (entropy)	0.086	0.091	0.092	0.049	0.231	0.087	0.084	0.059	0.116	0.106
TOPSIS evaluation (entropy)	7	5	4	10	1	6	8	9	2	3
AVERAGE FINAL EVALUATION	0.096	0.091	0.104	0.055	0.203	0.082	0.077	0.069	0.117	0.107
Final ranks	5	6	4	10	1	7	8	9	2	3
Differences in values, %	11.0%	2.3%	16.6%	22.3%	18.5%	9.7%	14.4%	18.0%	3.1%	0.5%

To verify if the results appear to be coherent, differences between minimal and maximal values of normalised values of cumulative criteria were calculated. They appear at the bottom of Table 7. We can observe that for countries where the difference between ranks was more significant, such as Denmark, Estonia, Finland, Lithuania, and the United Kingdom, the differences did not make up more than 16.6%. Therefore, the final ranks adequately reflect the state of International Technology Transfer among the countries in question. Discrepancies introduced by differences between weights are counting no more than one rank difference; the ones presented by choice of a method are more considerable because of differences between the intrinsic logic of methods and how data was transformed.

The results of the ranking suggest refraining from historical or geographical generalisations. The top first and fourth places were attained by the countries adjacent by geographical location, namely Ireland and the United Kingdom. A deeper analysis is required to better understand the underlying causes of the obtained ranking. A tool for analysing normalised values usually exposes and explains stronger and weaker positions of the alternatives in question (Podviezko, 2012).

Conclusions

The classical economic notion is that developed countries' companies export or lend technologies more broadly worldwide and seek a return on investment. Their government is in line with such organisations (having in mind security criteria). There are exceptional cases when less developed countries create new technologies, specifically in the current digital services sector, which does not require a significant investment. Technology suppliers want profitable operations complementing their strategy offensively or defensively, and the private technology recipients seek to get profit, expertise etc. The governments of developing countries are ready to absorb technologies and attract new ones having the potential to increase the level of development. The systemised measures covering the economic, the political-legal, the social, and the group of promotion and screening of R&D can be the instrument of policymakers of both countries.

The research attempts to evaluate and compare internal conditions for OECD Northern Europe countries to implement, develop and share technologies. For this purpose, a set of 16 quantitative criteria was assembled, creating a hierarchical criteria structure with four categories.

Two popular MCDA methods were chosen; one was newly proposed, a new objective method APROD of estimation of weights. It was used along with the popular objective entropy method of assessment of weights. Two sets of results with different weights were obtained by both MCDA methods and then compared. Results showed rather good correspondence for all the discussed sectors, including mining.

Lagging and prominent values of criteria were captured for the countries in question. Ireland attained the best position. It can serve as a benchmark for a few criteria but also has lagging positions outlined in the previous section. Such lagging and prominent positions for each country are as follows.

Ireland (rank 1) attained the best position. It thus can serve as a benchmark for all other countries in terms of such criteria where that country attained the best relative positions among the countries in question. It has maximum inward and outward FDI, maximal intellectual property payments, and the best enforcement of contracts, while most other criteria have rather good relative values except for lagging values of criteria, such as enrolment in master's, doctoral or equivalent, which makes less than a half of graduates; and proportion of ICT specialists in total employment, which makes only 3.8%. Sweden and Finland, which are next countries in the resulting rating (ranks 2 and 4 respectively), have excellent positions in five criteria: enrolment in master's, doctoral or equivalent; university-industry collaboration in R&D; tertiary graduates from STEM programmes; PCT applications; the proportion of citizens that have basic digital skills while Sweden has an outstanding magnitude of intellectual property payments; and Finland attained excellent property rights; FDI regulatory openness; and again, educational number of citizens that had basic digital skills positions. Other countries may improve their positions if they pay attention to the most lagging criteria. The UK (rank 3) is lagging in such positions as the number of master's and doctoral students, both inward and outward FDI; trust in government; protection of property rights; capital controls; percentage of individuals that had basic digital skills (only 60%). Denmark (rank 5) is lagging in high-technology exports as they make only 13.7% of the manufactured exports; legal enforcement of contracts, FDI regulation; FDI magnitudes, especially inward (35.8% of GDP); tertiary graduates from STEM programmes make only 41.6%. Estonia (rank 6) is lagging in both inward and outward FDI; especially in university-industry collaboration in R&D; has only 51.2 % of citizens with basic digital skills, only 6.5% of intellectual property payments of its total trade and mediocre number of applications for patents. Latvia (rank 7) is ought to make progress in promoting of its FDI outward investment as it makes only 15.5% of GDP; it finds itself at the bottom in terms of intellectual property payments as they make only 3.8% of the total trade; the country definitely considerably lacks trust in government; and finds itself at the bottom of the group of countries in terms of protection of property rights; it has low proportion of citizens with digital skills of the population, seekers of the master's and doctoral degrees, as well as graduates from STEM programmes; low number of patent applications. Lithuania (rank 8) is lagging by most part of the criteria, but having found the country at good positions in terms of proportion of ICT specialists; liberal controls of FDI, movement of capital, and services and trade, such prominent performance in mentioned areas shifts its place from the bottom by two ranks. Norway (rank 9) is lagging especially in terms of regulation criteria and in terms of legal enforcement of contract. By the definition of the latter criterion by Frazer, it means both high time cost required from the moment the lawsuit is filed until payment is received and high percentage of the debt required to process the lawsuit. Values of restrictiveness indices, both Services Trade and FDI Regulatory, provided by the OECD, as well as capital movement controls, are high. Trade restrictions criteria provide a rich source of information for trade policy makers, trade negotiators and researchers, and an instrument for impact assessment of trade liberalisation as is embedded by the OECD into its database. FDI restrictions are related to foreign equity limitations, discriminatory screening or approval mechanisms, employment of foreigners as key personnel, other operational restrictions, e.g. restrictions on branching and on capital repatriation or on land ownership by foreign-owned enterprises. Actual inward FDI is only 35.6% of GDP; lower volumes are noted only in Iceland and Finland. Both academic indices, university-industry collaboration in R&D and percentage of tertiary graduates from STEM programmes as well as intellectual property payment and patent application volumes appear to be quite moderate within the region. Norway appeared in lower position mostly because of factors mentioned above. According indices related to digital skills of the population and its educational level reveal that the country is among the leaders. For example, proportions of students involved in upper-level tertiary education and in master's or doctoral programs are inspiring. High-technology exports are rather high. The country is best-rated among the countries in question in terms of trust in government. Iceland (rank 10), which is now found at the bottom position, has an exceptionally high proportion of citizens with basic digital skills, high-technology exports, good protection of property rights and trust in government. Its main problem in terms of creating most favourable conditions for technology transfer is its restrictive politics also resulting in lowest FDI volumes in the region.

Some novel tools of the MCDA analysis were presented in the paper for the first time. The new estimation method of weights APROD produces a rather rarely available opportunity to create weights without needing to address experts. The method gleans particularities of the data by conveying the relative variability between maximal and minimal values within the values. The paper provides a logical grounding of the named method to be used with the specific normalisation of data in the SAW method, thus ensuring its prominence over other available methods. The new approach of comparing results obtained by different MCDA methods was presented and used. It allows better comparison of results by ranks and normalised values of the cumulative criteria obtained by different MCDA methods and by using sets of weights obtained by various methods. Also, what is even more important, it allows for gauging differences between evaluations.

A particular set of 16 criteria was chosen for the present research that describes conditions for the ITT in a country. The methodology retains the complete flexibility of the MCDA methods and allows for broadening the set of criteria in further studies.

Novelty and practical value of the obtained results.

The following new results in the field of economics have been obtained in the present investigation: theoretical factors of ITT development have been systemised. Based on this, a comparative analysis of the state of the Northern Europe countries was provided. Such a technique shall also be useful in comparing the ITT development trends for other countries, as well in revealing strength and conditional weaknesses of states under investigation.

The presented evaluation model has been verified by empirical research, the results of which may be helpful for scientists and practicians, looking for complex sets of ITT development factors of the countries or a particular region and dealing with the problems of the relationship between the different indicators.

Research limitations

Only sixteen indicators were included in this investigation. The number of criteria can be expanded for further studies, especially analysing the factors that can boost green technologies transfer.

References

Bozeman, B., Rimes, H., & Youtie, J. (2015). The evolving state-of-the-art in technology transfer research: Revisiting the contingent effectiveness model. *Research Policy*, 44(1), 34-49. https://doi.org/10.1016/j.respol.2014.06.008

Androniceanu, A., Georgescu, I. & Sabie, O.-M. (2022). The impact of digitalization on public administration, economic development, and well-being in the EU countries. *Central European Public Administration Review*, 20(1), 7–29.

Androniceanu, A., Nica, E., Georgescu, I., & Sabie, O. M. (2021). The influence of the ICT on the control of corruption in public administrations of the EU member states: a comparative analysis based on panel data. *Administratie si Management Public*, 37, 41-59. https://doi.org/10.24818/amp/2021.37-03

Burinskas, A., Holmen, R. B., Tvaronavičienė, M., Šimelytė, A., & Razminienė, K. (2021). FDI, technology & knowledge transfer from Nordic to Baltic countries. *Insights into Regional Development*, 3(3), 31-55. https://doi.org/10.9770/IRD.2021.3.3(2)

Derakhshani, S. (1983). Factors Affecting Success in International Transfers of Technology: A Synthesis, and a Test of a New Contingency Model. The Developing Economies, 2, 27-47. https://doi.org/10.1111/j.1746-1049.1984.tb00650.x

Dobrovolskienė, N., & Pozniak, A. (2021). Simple Additive Weighting versus Technique for Order Preference by Similarity to an Ideal Solution: which method is better suited for assessing the sustainability of a real estate project. *Entrepreneurship and Sustainability Issues*, 8(4), 180-196. http://doi.org/10.9770/jesi.2021.8.4(10)

Ferreira, J., Fernandes, C.I., & Ferreira, F. (2020). Technology transfer, climate change mitigation, and environmental patent impact on sustainability and economic growth: A comparison of European countries. *Technological Forecasting and Social Change*, 150. https://doi.org/10.1016/j.techfore.2019.119770.

Hall, B. H. (2022). Patents, innovation, and development. International *Review of Applied Economics*. https://doi.org/10.1080/02692171.2021.2022295

Holubčík, M., Soviar, J., & Lendel, V. 2022. Sustainable cooperation management - insights from a selected company. *Entrepreneurship and Sustainability Issues*, 10(2), 429-447. http://doi.org/10.9770/jesi.2022.10.2(27)

Jiaoe, W., Fangye, D., Mingquan, W., & Weidong, L. (2021). Embedded technology transfer from an institution and culture nexus perspective: Experiences from the Mombasa-Nairobi Standard-Gauge Railway. *J. Geogr. Sci*., 31(5), 681-698.: https://doi.org/10.1007/s11442-021-1865-5

Knoema (2023). www.knoema.com, available in the internet, accessed on 4 February, 2023.

Kowalski, P., Rabaioli, D., & Vallejo, S. (2017). International Technology Transfer measures in an interconnected world: Lessons and policy implications. OECD Trade Policy Papers, 206. https://doi.org/10.1787/ada51ec0-en

Kučera, J., & Fiľa, M. (2022). R&D expenditure, innovation performance and economic development of the EU countries. *Entrepreneurship and Sustainability Issues*, 9(3), 227-241. http://doi.org/10.9770/jesi.2022.9.3(14)

Lazaroiu, G., Androniceanu, A., Grecu, I.,; Grecu, G. & Negurita, O. (2022). Artificial intelligence-based decision-making algorithms, Internet of Things sensing networks, and sustainable cyber-physical management systems in big data-driven cognitive manufacturing. *Oeconomia Copernicana*, 13(4), 1047-1080. https://doi.org/10.24136/oc.2022.030

Podviezko, A., Kurschus, R., & Lapinskiene, G. (2019). Eliciting weights of significance of criteria for a monitoring model of performance of SMEs for successful insolvency administrator's intervention. *Sustainability*, 11(20). https://doi.org/10.3390/su11205667

Khorshid, M., Rezk, M. R., Ismail, M., Piccinetti, L., Radwan, A., Helmy, O., & Sakr, M. M. (2023). Research, development and innovation in business enterprises: experience from Egypt. *Insights into Regional Development*, 5(1), 41-58. https://doi.org/10.9770/IRD.2023.5.1(3)

Kwadwo O. S., Leiringer, R. (2021). International technology transfer through projects: A social construction of technology perspective. *International Journal of Project Management,* 39(8), 902-914. https://doi.org/10.1016/j.ijproman.2021.08.004

Laužikas, M., Miliūtė, A., Baltaduonis, T., & Mačiulskis, Ž. (2022). Impacts of modern technologies while identifying and unleashing intrapreneurs' potential. Entrepreneurship and Sustainability *Issues*, 10(2), 217-238. http://doi.org/10.9770/jesi.2022.10.2(14)

Liu, M., Lo, K., Westman, L., & Huang, P. (2022). Beyond the North-South divide: The political economy and multi-level governance of international low-carbon technology transfer in China. *Environmental Innovation and Societal Transitions*, 44, 194-204. https://doi.org/10.1016/j.eist.2022.07

Madu, C.N. (1989). Transferring technology to developing countries - Critical factors for success. *Long Range Planning*, 22(4), 115-124. https://doi.org/10.1016/0024-6301(89)90089-7.

Maskus, K. E. (2004). Encouraging International Technology Transfer. Intellectual Property Rights and Sustainable Development. Vol. 7. Available on the Internet https://www.files.ethz.ch/isn/111411/2010_01_encouraging-international-technology-transfer.pdf

Matthew, G., Mirjam, K., Birthe, S., & Mike, W. (2019). The technology transfer ecosystem in academia. An organisational design perspective. *Technovation*, 82, 35-50.

Menaldo, V., & Wittstock, N. (2021) Does technology transfer from the US to China harm American firms, workers, and consumers? A historical and analytic investigation. *Economic and Political Studies*, 9(4), 417-446. https://doi.org/10.1080/20954816.2021.1933768

Moikangoa, N. (2000). The Social Design of Technology Transfer into the Sustainable Development Domain, IFAC Proceedings, 33(18), 1-7. https://doi.org/10.1016/S1474-6670(17)37112-4

Noh, H., & Lee, S. (2019). Where technology transfer research originated and where it is going: a quantitative analysis of literature published between 1980 and 2015. *The Journal of Technology Transfer*, 44(3), 700-740.

Palaco, I., Kim, S., & Park, M. (2022). Exploring capabilities of international technology transfer intermediaries between emerging and developed countries. *J Technol Transf.*, 47, 307-352. https://doi.org/10.1007/s10961-021-09849-2

Podviezko, A. (2012). Augmenting multi-criteria decision aid methods by graphical and analytical reporting tools. *Lecture Notes in Business Information Processing*, 106. https://doi.org/10.1007/978-3-642-29231-6-19

Podviezko, A. (2014). Distortions introduced by normalisation of values of criteria in multiple criteria methods of evaluation. *Proc. of the Lithuanian Mathematical Society. Ser.A*, 55, 51-56. https://doi.org/10.15388/LMR.A.2014.10

Puig, D., Haselip, J.A., & Bakhtiari, F. (2018). The mismatch between the in-country determinants of technology transfer, and the scope of technology transfer initiatives under the United Nations Framework Convention on Climate Change. *Int Environ Agreements*, 18, 659–669 https://doi.org/10.1007/s10784-018-9405-1

Radavičius, T., & Tvaronavičienė M. (2022). Digitalisation, knowledge management and technology transfer impact on organisations' circularity capabilities. *Insights into Regional Development*, 4(3), 76-95. http://doi.org/10.9770/IRD.2022.4.3(5)

Rigo, D. (2021). Global value chains and technology transfer: new evidence from developing countries. *Rev World Econ.*, 157, 271-294. https://doi.org/10.1007/s10290-020-00398-8

Roberts, E.B., & Hauptman, O. (1986). The process of Technology Transfer to the New Biomedical and Pharmaceutical Firm. *Research Policy*, 15, 107-119.

Roszkowska, D. (2013). Approaches to International Technology Transfer Measurement – An Overview, Optimum. *Studia Ekonomiczne*, 51-63. https://doi.org/10.15290/ose.2013.05.65.04

Roy, B. (2016). Paradigms and challenges. In International Series in Operations *Research and Management Science*, 233, 19-39. https://doi.org/10.1007/978-1-4939-3094-4_2

Shouwu, J., Yong, X., & Zheng, L. (2016). Analysis on the Factors Influencing the International Technology Transfer Based on ISM Model. *International Journal of Economics and Finance*, 8(3).

Steruska, J., Simkova, N., & Pitner, T. (2019). Do science and technology parks improve technology transfer? *Technology in Society*, 59. https://doi.org/10.1016/j.techsoc.2019.04.003

UNCTAD. (2014). United Nations Conference on Trade and Development. Studies in Technology Transfer. Available on the Internet https://unctad.org/system/files/official-document/dtlstict2013d7_en.pdf

World Intellectual Property Organization (WIPO). (2011). Standing Committee on the Law of Patents. Available on the Internet <https://www.wipo.int/edocs/mdocs/scp/en/scp_17/scp_14_4_rev_2.pdf>

Zavadskas, E. K., & Podvezko, V. (2016). Integrated Determination of Objective Criteria Weights in MCDM. International *Journal of Information Technology & Decision Making*, 15(02), 267-283. https://doi.org/10.1142/S0219622016500036

Zhao,Y., Zhou, Z., Zhang,K., Huo, Y., Sun, D., Zhao, H., Sun, J., & Guo, S. (2023). Research on spillover effect between carbon market and electricity market: Evidence from Northern Europe. *Energy*, 263. https://doi.org/10.1016/j.energy.2022.126107