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International Technology Transfer, Innovation and Economic Development of European Union Countries in 2008-2017

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Abstract:

Purpose: *The article aims to assess the extent to which International Technology Transfer (ITT) can influence the innovation level of European Union (EU) countries and, as a result, accelerate their economic development. This is vital from the point of view of the developing countries which are striving to narrow the development gap as rapidly as possible.*
Design/Methodology/Approach: *The study uses a soft modelling method which makes it possible to measure and analyse the dependencies between variables than cannot be directly observed, i.e. latent variables. The soft model consists of two sub-models: an internal one, describing the relationships between the latent variables, and an external one, characterising the latent variables by means of observable variables. The statistical data used for estimating the model come from Eurostat, the World Bank, and the European Innovation Scoreboard database and span the years 2008-2017.*
Findings: *The results of the modelling indicated a positive impact of ITT on innovation levels in EU countries and a positive impact on both ITT and innovation levels on the economic development of the studied countries in the period 2008-2017. The influence of innovation levels on economic development proved to be stronger than the influence of ITT.*
Practical Implications: *The results of the conducted study can have a practical application and serve as an instrument of innovation policies, industrial policies, or as a tool helpful in creating conditions for innovation systems.*
Originality/Value: *The article points to the methods and extent of gaining knowledge and technologies as prerequisites of higher innovativeness of EU countries, which constitutes an original approach to technological processes as a component of economic development.*

Keywords: *International technology transfer, innovation, economic development, European Union countries, soft modelling method.*

JEL Codes: *C33; C38; O11; O30*

Paper Type: *Research article.*

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1. Introduction

Technological progress can manifest itself as radical improvements or gradual changes, i.e. the so-called incremental development. Radical development arises as a result of Schumpeterian 'creative destruction', where new technological phenomena are an effect of dynamic, innovative competition instead of static price-based competition. Simple price-based competition results merely in lowering the prices of consumer goods. Meanwhile, non-price competition leads to greater usefulness of products and their better utilisation. This enables the creation of a mixture of cheap goods (of low technological level) and more expensive (innovative) ones. This kind of rivalry forces enterprises to pursue quality growth and seek the potential to create novel market solutions – new in terms of technology, organisations and marketing techniques. Incremental development, on the other hand, relies on small but consistent improvements (Ayres, 1996).

The purpose of the article is to assess the extent to which International Technology Transfer (ITT) may influence the innovation level of European Union (EU) countries and, as a result, speed up their economic development. This issue is particularly important from the point of view of developing countries, for whom ITT provides a prime opportunity to achieve higher innovation performance. To attain the objective, the authors use a soft modelling method, which makes it possible to measure and analyse the dependencies between variables than cannot be directly observed. The applied method made it possible, moreover, to construct synthetic measures of the analysed economic categories, and thus to order and classify the EU countries under review according to ITT, innovation level, and the level of economic development.

The structure of the paper is as follows: Section 2 presents a review of the literature on international technology transfer, innovation, and development processes. Section 3 contains a description of the applied research method of soft modelling. In section 4, specification of the soft model is conducted. Section 5 presents the results of the study. The last section summarises the findings and offers a conclusion.

2. Literature Review

2.1 Knowledge in ITT Processes

Access to new knowledge through technology diffusion, either via market or non-market channels, is a less time-consuming and capital-intensive process than generating knowledge by means of a company's own R&D. Research and development is also associated with considerable economic risk. Thanks to the process of transfer, it is possible to achieve diffusion of technology during which innovations can undergo changes, allowing the primary inventor to receive feedback information. Diffusion is also indispensable for society as a whole to derive benefits from innovative efforts. Diffusion should be treated as a desirable complement to technical innovations. Only together can the emergence of innovations and their diffusion through technology transfer create technological progress in an economy (Ciborowski and Skrodzka, 2019). The key role of technological change in growth of productivity provides a counterweight to the traditional perception of technological progress as a spontaneous process whose effects, and not causes, should be investigated. Transfer of purely technical knowledge does not guarantee its efficient absorption (Günsel, 2015). It also diminishes the positive influence of technology transfer on the innovative performance of the economy which receives a technology. A substantial role in this process is also played by the capacity to create, modify and adapt technologies, other than the so-called industrial production capacity, associated with the technical possibilities to apply investment goods (Radosevic, 1999).

Effective technology transfer should encompass the greatest possible scope of knowledge resources, not only those regarding technology itself but also its organisational, marketing, cultural and social aspects. It should be stressed that practical know-how and experience are a vital component of technical information flow, indispensable for implementing and applying new technologies. Smooth transmission of technological solutions among economic entities, particularly ones located in different countries, requires therefore simultaneous flow of knowledge through several channels. Apart from the transfer of codified knowledge, embodied in investment goods and documentation, there should occur at the same time a flow of uncodified knowledge, e.g. technical support in the form of training and temporary migration of qualified staff, needed to help properly implement and supervise further development of technologies transferred via market channels (Andrenelli *et al.*, 2019; United Nations Conference on Trade and Development, 2014).

International Technology Transfer (ITT) occurs whenever technical knowledge becomes available in a given country in any other way than through own research activity or accumulation of experience. It happens, therefore, as a result of established international co-operation or purchase of technological solutions abroad. ITT can be otherwise described as a mechanism of information flow across country borders and its effective diffusion in the receiving country (see Maskus, 2004, pp. 7). This approach emphasises the consequences of transfer as a factor which improves the quality of technological processes and the utilisation of innovative solutions.

Transferring of technologies between various types of economic entities and institutions is a fundamental feature of all the definitions of ITT. Also important is the effect that the implementation of transferred technical knowledge has on the new economic environment, i.e. application of innovative ideas. What makes defining technology transfer somewhat difficult is the uncertainty as to how to describe the way in which knowledge is transferred, which determines its classification as the process of technology transfer. Some authors point out the contractual, chargeable, and purposeful nature of the transfer process, differentiating it from diffusion, which is a semantically broader concept (Bozeman, 2000).

2.2 Determinants of Technological Change

The pace of technological divergence depends on the intensity with which new knowledge is acquired by domestic companies and the intensity with which capital for new foreign technologies is raised. The core of international technology transfer is therefore the rate at which new solutions are absorbed by the enterprises which receive technologies (Audretsch *et al.*, 2012).

The key benefits consist in the fact that the character of production becomes more complex and that higher technology sectors develop. Moreover, by undertaking international co-operation, enterprises increase R&D expenditure, thus increasing technological intensity and the level of technological advancement of production. Thirdly, international connections make it possible to broaden the scope of new technologies used onto a higher number of industries or sectors. Accumulation of resources and capacities in less technologically developed branches in the long term prompts enterprises to seek other, more innovative forms or scopes of activity (from processing to R&D). This type of processes must go hand in hand with the development of human resources (knowledge, experience, skills, co-operation) because of their inevitable complementarity and the tendency towards greater participation of enterprises in R&D. Further phases of attaining higher levels of technological development require greater efficiency in absorbing new solutions (Hoekman *et al.*, 2005).

The pace of technology transfer will quicken when transnational enterprises increase the flow of 'soft' technologies, which will contribute to the growth of competitive advantages as regards the utilisation of non-embodied technologies. The absorption capacities of foreign subsidiaries must be reinforced in order to make the development of the received technologies possible.

The organisational strategies of companies must abandon the transfer of existing technologies in favour of transferring knowledge and increasing qualifications to boost the research potential and gain development benefits (see Daim *et al.*, 2014, pp. 3–22). The process of increasing the productivity of technology transfer, and thus dynamising economic convergence, is discontinuous. Enterprises involved in this process must possess specific knowledge and meet certain requirements. Changes in the character of knowledge and the mechanisms of accessing technologies range from simple price competition, to subcontracting or technological alliances. This continues until domestic companies improve, or introduce new, superior business strategies concerning organisation, finances, or technologies.

2.3 Technology in Economic Development

In the processes of economic development a crucial role is played by the technological factor, which has a decisive influence on the character and rate of the growth of highly developed countries through altering the structure of production and modernisation of branches. What is more, it also entails organisational changes in the structures of industries. It enforces greater concentration of outlays in high-risk enterprises and enables conducting research and production in new organisational arrangements, thanks to which production can move to the small and medium enterprises sector. This leads to the emergence of new competitive structures.

Such an effect of technology on economic development and the conditions of internal and external competition indicate an increased importance of microeconomic factors, which influence flexibility and innovativeness, as well as the capacity to adapt to the changing competitive conditions. It stems from the above that countries which strive to foster conditions for technological development thanks to high R&D expenditure, creation of formal and legal infrastructure and pursuing appropriate state policies pave the way for the construction of competitive micro- and macroeconomic structures.

The international division of the technological capacities of particular economies lies at the core of technological partnership and co-operation. For enterprises, the internationalisation of technological activity is a necessary step, although it does not always generate only benefits. On the contrary, it is frequently associated with potential threats. This argument plays a significant part in the debate regarding not so much the process of globalisation itself as the possibilities to concentrate/disperse innovation-boosting activities. Long term objectives should include influencing structural technological changes and a narrowing of the development gap to more advanced countries. This is why technology transfer ought to be a starting point for in-company industrial solutions and growth of innovation.

Foreign technologies are among the main factors of developing the industrial potential of less developed countries through investments, marketing channels, technologies, gradual absorption and adaptation of imported knowledge, and the enhancement of qualifications. Direct foreign investments, joint undertakings, licence agreements, agreements with the producers of original equipment, and other similar transactions have been instrumental for industrial success in some of the less developed countries. To a large extent, they used import of technologies as a means of education and a point of departure for further innovations.

Technology transfer can play a similar part in strengthening the economic advancement of developing countries. It can increase their competitiveness in international markets provided that it is used for educational purposes and that it is co-ordinated with the development of domestic technologies.

Nowadays, the discussion of ITT revolves mainly around the possibility of using imported technologies and transforming them into a dynamic factor of innovative growth in domestic enterprises. The innovative capacities are embodied in the resources of companies and are the primary factor capable of accelerating economic development.

3. Research Methodology

This research uses the method of soft modelling developed by H. Wold (1980; 1982). A detailed description of the method and its generalization can be found in Rogowski (1989; 1990). Soft modelling allows users to examine links between variables which are not directly observable (latent variables). The values of these variables cannot be directly gauged because of the lack of a widely accepted definition or method of their measurement. Currently, soft models are included in the group of structural equation models, estimated by the partial least squares method – SEM-PLS (Hair *et al.*, 2014).

The soft model consists of two submodels: an internal one (structural model) and an external one (measurement model). The internal submodel describes dependencies between latent variables implied by the assumed theoretical model. Formally, the internal submodel can be expressed as (see Rogowski, 1990, pp. 34–35; Esposito Vinzi *et al.*, 2010, pp. 27):

$$\mathbf{\Xi_{end}} = \mathbf{\Xi_{end}}\,\mathbf{B} + \mathbf{\Xi_{egz}}\mathbf{C} + \mathbf{V}, \tag{1}$$

where

$\mathbf{B} = [b_{ij}]$ – n-square matrix with a diagonal of zeroes,

$\mathbf{C} = [c_{ij}]$ – $((k\text{-}n)\times n)$ – dimensional matrix of structural parameters associated with endogenous and predetermined variables, respectively,

$\mathbf{V} = [v_j]$ – n-dimensional vector of random components with expected values equal to zero and finite variances,

$\mathbf{\Xi_{end}} = [\xi_1, \ldots, \xi_n]$ – n-dimensional row vector of unlagged endogenous variables,

$\mathbf{\Xi_{egz}} = [\xi_{n+1}, \ldots, \xi_k]$ – $(k\text{-}n)$-dimensional row vector of predetermined theoretical variables.

Additionally, it is assumed that the random component of the j-th equation v_j is not correlated with this equation's independent variables ($j = 1, \ldots, n$).

In the external model, latent variables are defined by means of observable variables (indicators). Indicators allow for indirect observation of latent variables and are selected on the basis of a theory or the researcher's intuition. A latent variable can be defined inductively: the approach is based on the assumption that indicators form latent variables (formative indicators), or deductively, based on the premise that indicators reflect their theoretical notions (reflective indicators). In the deductive approach, a latent variable – as a theoretical notion – is a starting point in the search for empirical data (the variable precedes a given indicator). In the inductive approach, it is indicators that precede the latent variable which they form. Under both approaches, latent variables are estimated as weighted sums of their indicators. However, depending on the definition, indicators should have different statistical properties: lack of correlation in the case of the inductive definition and high correlation in the case of the deductive definition (Wold, 1982; Rogowski, 1990, pp. 35–37).

The formal notation of external relations is as follows (see Rogowski, 1990, pp. 36–37; Esposito Vinzi *et al.*, 2010, pp. 28):

$$\underset{j=1,\dots,k}{\forall}\ \underset{t=1,\dots,T}{\forall}\ \xi_{tj} = \sum_i w_{ij} x_{tij}\ . \qquad (2)$$

where
ξ_{tj} – t-th value of variable ξ_j,
x_{tij} – t-th value of i-th indicator of variable ξ_j,
w_{ij} – weight associated with x_{ij}, when defining ξ_j,

Therefore, it is assumed that each latent variable is a weighted sum of its indicators. Moreover, for each reflective indicator, the relation measuring the strength of reflection is given (see Rogowski, 1990, pp. 37; Esposito Vinzi *et al.*, 2010, pp. 28):

$$\underset{j=1,\dots,k}{\forall}\ \underset{t=1,\dots,T}{\forall}\ x_{tij} = \pi_{ij0} + \pi_{ij}\xi_{tj} + \mu_{tij}\,, \qquad (3)$$

where
π_{ij} – factor loading measuring the strength of reflection of the latent variable ξ_j by its i-th indicator,
μ_{tij} – random component with expected values equal to zero.

Moreover, it is assumed that random components are not correlated in time (no autocorrelation) or between equations, or with the latent variables. Additionally, a unit-variance ξ_j is also assumed.

The estimation of soft model parameters is performed by means of the partial least squares method – PLS (more in: Lohmöller, 1989; Rogowski 1990; Esposito Vinzi *et al.*, 2010). The quality of the model is assessed using coefficients of determination (R^2), calculated for each equation. The significance of the parameters is analysed by means of standard deviations, calculated with the help of the Tukey's test (Miller, 1974; Rogowski, 1990, pp. 53–54)[3]. Besides, in the case of the external model, estimators of factor loadings can be treated as the degree of fit between each indicator and the latent variable which they define. The prognostic quality of the model is assessed by means of the Stone-Geisser (S-G) test (Geisser, 1974; Wold, 1982), which measures the accuracy of a prognosis performed on the basis of the model in juxtaposition to a trivial prognosis. The tests statistics take values from the range of (–∞,1>. For an ideal model, the value of the test equals 1 (prognoses are accurate in comparison with trivial prognoses). If the value is equal to zero, the quality of the model's prognosis is, on average, identical to the quality of a trivial prognosis. Negative values indicate low quality of the model (Rogowski, 1990, pp. 52–53).

By applying the partial least square method, an assessment of the latent variables is made. Latent variables can be treated as values of synthetic measures. They can be used to produce a linear ordering of the studied objects. These values depend not only on external relationships, but also on the relationships among the latent values assumed in the internal model. This means that the cognitive process is not only dependent on the definition of a given notion, but also on its theoretical description.

4. Specification of the Soft Model

The model which was used for realisation of the research objectives contained the following two equations:

$$ED = \alpha_{11}INN + \alpha_{12}ITT + \alpha_{10} + v_1, \quad (4)$$

$$INN = \alpha_{21}ITT + \alpha_{20} + v_2, \quad (5)$$

where
ED – the level of economic development,
INN – the level of innovation,
ITT – international technology transfer,
α_{ij} – structural parameter of the model, $i = 1,2$, $j = 0,1,2$.
v_i, – random components, $i = 1,2$.

In the model, the deductive approach to defining latent variables was used, i.e. each latent variable as a theoretical notion was a starting point for search for empirical data. The choice of indicators was made on the basis of substantive and statistical criteria. From the statistical perspective, the following things were taken into

[3] *When examining the significance of parameters, the so-called "2s" rule is used, according to which a parameter significantly differs from zero if double standard deviation does not exceed the value of the estimator of this parameter.*

account: diversity of indicator values, measured by the coefficient of variation[4] (critical value of the coefficient was established at 10%) and the quality of the estimated model (significance of model parameters, coefficient of determination, S-G test). The indicators which passed substantive and statistical verification are presented in Table 1.

The statistical data were obtained from the databases of the World Bank and Eurostat, as well as from the European Innovation Scoreboard report. The data were prepared for estimation in the following stages. First, each database was checked for missing data. Due to data shortages Great Britain was excluded from further analysis. Next, for each of the 27 remaining countries, mean values of each indicator for years 2008-2017 were calculated. In the case of most indicators data for 2008-2017 were available (see Table 1). The only exceptions were indicators *ITT*4, *ITT*5 and *INN*. In their case, data availability depended on the frequency of the Community Innovation Survey (CIS) conducted by Eurostat. To overcome this problem, mean indicator values were established on the basis of available data. Similarly, as regards indicator *ITT*6, its mean values for the years 2009-2017 were calculated.

Table 1. *Indicators of latent variables ITT, INN and ED qualified for the model*

Symbol of indicator	**Indicator**	**Source**	**Availability of data**	**Type of indicator**
ITT latent variable				
*ITT*1	Foreign direct investment, net inflows (% of GDP).	WB	2008-2017	S
*ITT*2	High-tech import (% of total import).	E	2008-2017	S
*ITT*3	Enterprises engaged in any type of innovation co-operation with a partner in EU countries, EFTA or EU candidates countries , except a national partner (% of total enterprises).	E	2008-2017	S
*ITT*4	Enterprises engaged in any type of innovation co-operation with a partner in United States (% of total enterprises).	E	2008,2010, 2012,2014, 2016	S
*ITT*5	Enterprises engaged in any type of innovation co-operation with a partner in China or India (% of total enterprises).	E	2008,2010, 2012,2014, 2016	S
*ITT*6	International scientific co-publications (per million population)	EIS	2009-2017	S

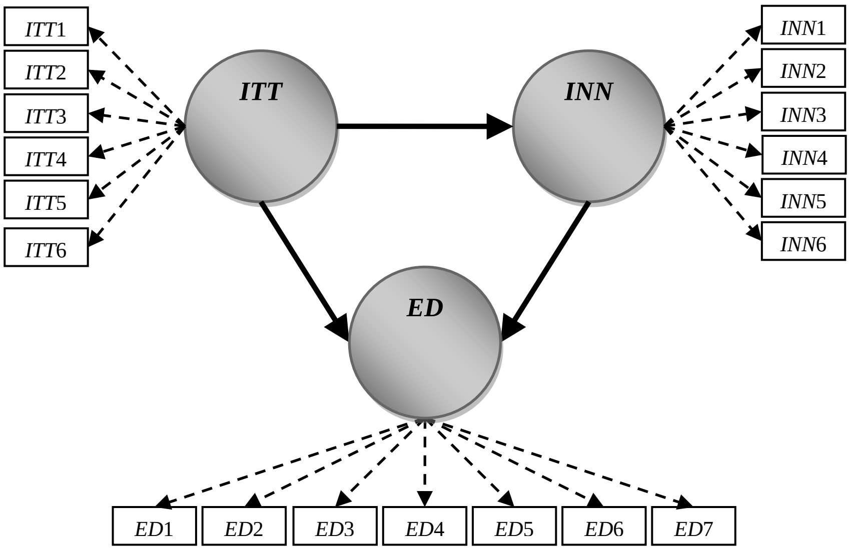
[4] *Calculated as ratio of standard deviation to arithmetic mean, expressed in percents.*

Symbol of indicator	**Indicator**	**Source**	**Availability of data**	**Type of indicator**
INN latent variable				
*INN*1	Total intramural R&D expenditure (% of GDP).	E	2008-2017	S
*INN*2	Business enterprise R&D expenditure (% of GDP).	E	2008-2017	S
*INN*3	High-tech export (% of total export).	E	2008-2017	S
*INN*4	Employment in knowledge-intensive activities (% of total employment).	E	2008-2017	S
*INN*5	Innovative enterprises (% of total enterprises).	E	2008,2010, 2012,2014, 2016	S
*INN*6	Patent applications to the EPO (per million population).	E	2008-2017	S
ED latent variable				
*ED*1	GDP per capita (PPP, constant 2011).	WB	2008-2017	S
*ED*2	Gross value added per employee (PPP, current prices).	E	2008-2017	S
*ED*3	Gross value added in agriculture, forestry and fishing (% of total gross value added).	E	2008-2017	D
*ED*4	Gross value added in professional, scientific and technical activities; administrative and support service activities (% of total gross value added)	E	2008-2017	S
*ED*5	Employment rate of people aged 20-64 (%)	E	2008-2017	S
*ED*6	Mean equivalised net income (PPP, current prices).	E	2008-2017	S
*ED*7	Percentage of people at risk of poverty or social exclusion (%).	E	2008-2017	D

Notes: *WB – World Bank, E – Eurostat, EIS – European Innovation Scoreboard, S – stimulant, D – destimulant.*

The latent variable *ITT* is defined by means of six indicators concerning the most frequent and the most significant ITT channels. The latent variable *INN* is defined by six indicators reflecting the capacity to create and diffuse innovation. The latent variable *ED* is defined by means of seven indicators pertaining to economic potential, employment rate, and standards of living.

Figure 1. *Schematic diagram of internal and external relationships of the soft model*



The model was estimated using the partial least squares method, which enables simultaneous estimation of the external model parameters (weights and factor loadings) and the internal model parameters (structural parameters). The estimation was conducted with the help of PLS software[5].

5. Results of Estimation

The results of the estimation of the external model are presented in Table 2. Each weight represents the relative share of a given indicator's value in the estimated value of a latent variable. Factor loadings are coefficients of correlation between indicators and latent variables, thus indicating the degree and direction in which the variability of an indicator reflects the variability of a latent variable. The ordering of indicators according to weight is performed when a latent variable is defined inductively. In the deductive approach, which was applied in this research, it is the factor loadings that are interpreted. The following interpretation of the π_{ij} factor loading was assumed:

- $|\pi_{ij}| < 0.2$ – no correlation,
- $0.2 \leq |\pi_{ij}| < 0.4$ – weak correlation,
- $0.4 \leq |\pi_{ij}| < 0.7$ – moderate correlation,
- $0.7 \leq |\pi_{i}| < 0.9$ – strong correlation,
- $|\pi_{ij}| \geq 0.9$ – very strong correlation.

[5] *The software was developed by Prof. J. Rogowski from the Faculty of Economics and Management, University of Bialystok and is free of charge.*

In terms of the values of the estimated parameters, the results are consistent with the expectations. Being stimulants, all the indicators have positive estimations of weights and factor loadings. Moreover, all the parameters are statistically significant, in accordance with the "2s" principle.

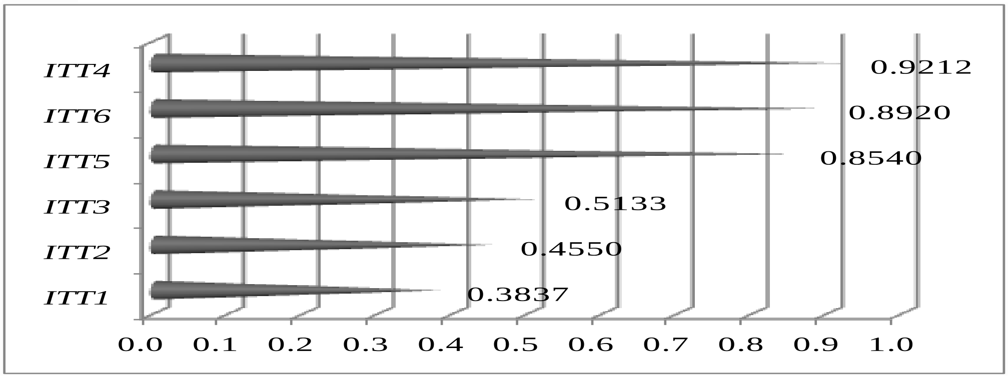
Table 2. *Estimations of external relationships parameters in the soft model*

Symbol of indicator	**Weight**	**Standard deviation**	**Factor loading**	**Standard deviation**
latent variable *ITT*				
*ITT*1	0.1673	0.0194	0.3837	0.0212
*ITT*2	0.2215	0.0076	0.4550	0.0143
*ITT*3	0.0762	0.0025	0.5133	0.0070
*ITT*4	0.2832	0.0051	0.9212	0.0075
*ITT*5	0.2352	0.0043	0.8540	0.0092
*ITT*6	0.3746	0.0046	0.8920	0.0046
latent variable *INN*				
INN1	0.1942	0.0070	0.8558	0.0103
INN2	0.1966	0.0071	0.8606	0.0098
INN3	0.1766	0.0086	0.5112	0.0144
INN4	0.2593	0.0119	0.8124	0.0107
INN5	0.2093	0.0042	0.8347	0.0020
INN6	0.2133	0.0056	0.8863	0.0074
latent variable *ED*				
ED01	0.1828	0.0154	0.8976	0.0444
ED02	0.1654	0.0118	0.8537	0.0776
ED03	-0.1946	0.0196	-0.9237	0.0725
ED04	0.1579	0.0153	0.7715	0.0769
ED05	-0.1168	0.0111	-0.5171	0.0362
ED06	0.2040	0.0167	0.9486	0.0551
ED07	-0.1770	0.0163	-0.7867	0.0736

Figures 2, 3, and 4 present ordering of the indicators of each of the latent variables in terms of the absolute values of factor loadings, i.e. in terms of the strength of the relationship between the values of the latent variable and the values of the indicators.

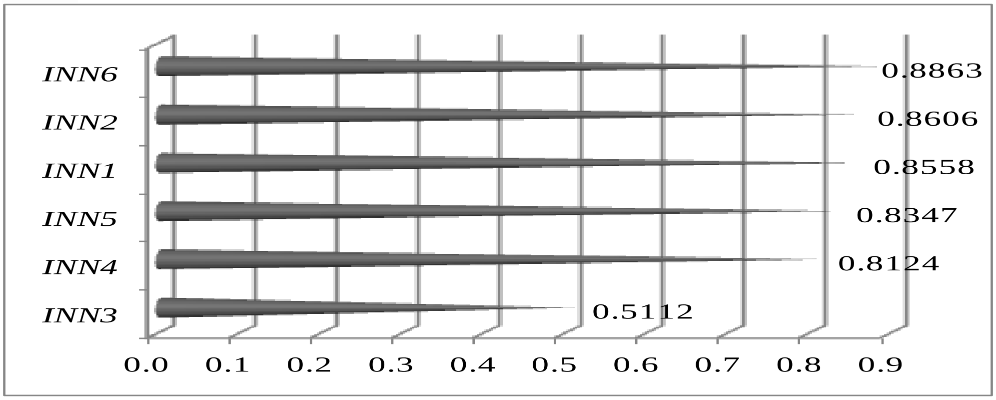
The latent variable *ITT* is very strongly related with the indicator "Enterprises engaged in any type of innovation co-operation with a partner in United States" (*ITT*4). Two indicators "International scientific co-publications" (*ITT*6) and "Enterprises engaged in any type of innovation co-operation with a partner in China or India" (*ITT*5) have a strong relationship with the variable. The indicator "Foreign direct investment, net inflows" (*ITT*1) was found to have the weakest correlation with the variable.

Figure 2. *Ordering of latent variable ITT indicators according to factor loading values*



The development of European economies was, to a large extent, based on technological co-operation with the USA. This happened as a result of the strong supply of high-technology in American companies and the intense relocation of technology-related businesses from the USA to Europe. The relocation took the form of licence sales, as well as fusions and takeovers. The obtained results also demonstrate that the increase in European technological resources was associated with closer co-operation with Chinese and Indian firms. European enterprises expanded their activities in Asian markets through joint technological projects, and sales of know-how or licences. Foreign direct investments have become an increasingly frequently employed ITT channel.

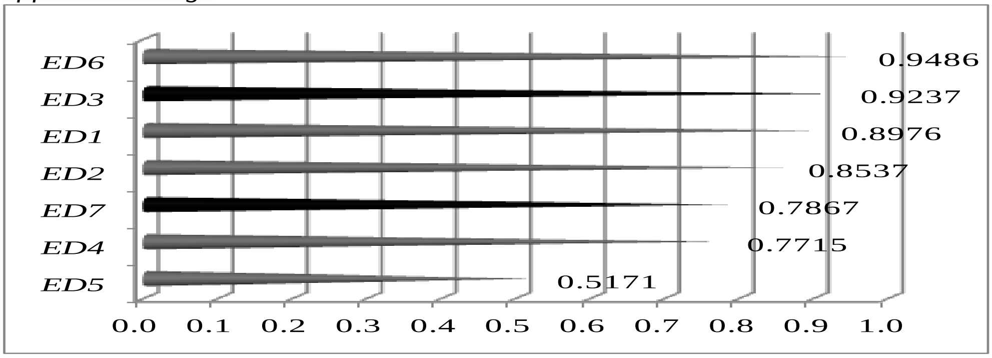
Figure 3. *Ordering of latent variable INN indicators according to factor loading values*



Five out of six indicators of the latent variable *INN* are strongly correlated with it. The strongest correlation was found to exist in the case of “Patent applications to the EPO” (INN6). The indicator “High-tech export” (INN3) has the weakest correlation with the latent variable.

The great importance of patents and R&D expenditure stems from the nature of innovative activity in EU countries. It primarily involves heading towards a knowledge-based economy, the consequence of which is that innovation policies play a significant part in economic processes, but the role of the market is weakened. Therefore, the objective is to maintain high levels of expenditure at every stage of innovation processes and to subject them to legal restrictions. Implementation and commercial effects are of lesser importance.

Figure 4. *Ordering of latent variable INN indicators according to absolute values of factor loadings*



Note: *The darker colour relates to the destimulants.*

The strength of the correlation between latent variable *ED* and the indicators varies. Two indicators “Mean equivalised net income” (*ED*6) and “Gross value added in agriculture, forestry and fishing” (*ED*3) show very strong correlations with the variable, one – “Employment rate of people aged 20-64” (*ED*5) – is moderately correlated with it, whereas the other four have strong correlations. This is associated with the deep involvement of the government sector in economic processes, manifesting itself in strong distribution of income and pursuit of development directions prescribed by state policies.

The outcomes of the internal model estimation are illustrated by equations (6-7). The brackets contain standard deviations calculated by means of the Tukey's test.

$$ED = 0.7845 \cdot INN + 0.1326 \cdot ITT - 2.1554, \quad R^2 = 0.62 \qquad (6)$$
$$INN = 0.7870 \cdot ITT + 1.3944, \quad R^2 = 0.80 \qquad (7)$$

The structural parameters are statistically significant ("2s" rule). Wartości współczynników determinacji kształtują się na zadowalającym poziomie i świadczą o tym, iż zróżnicowanie zmiennych objaśnianych jest w stopniu umiarkowanym (w przypadku pierwszego równania) oraz wysokim (w przypadku drugiego równania) wyjaśniane przez model. The values of the Stone-Geisser test, which verifies the soft model in terms of its predictive usefulness (see Table 3) are positive, which proves the model's high prognostic quality.

Table 3. *Stone-Geisser test results*

Symbol of indicator	**Value of S–G test statistic**
ED01	0.4413
ED02	0.3275
ED03	0.4920
ED04	0.3578
ED05	0.1854
ED06	0.6232
ED07	0.4108
General	0.3751

Equation (6) indicates that in the years 2008-2017, both international technology transfer and the level of innovation had a positive impact on the level of economic development of the examined EU countries. The significance of innovation was found to be greater than that of ITT. Equation (7), on the other hand, demonstrates a positive influence of international technology transfer on the level of innovation in the studied EU countries over the period under consideration.

ITT has ceased to be the most important development factor due to the appearance of barriers to purchasing technologies abroad, as their quality is much lower than in the EU countries. Therefore, the majority of European countries are faced with the necessity to create their own innovative solutions, relying on higher R&D expenditure and a broadening of the scope of scientific exploration. It has also become vital for companies to engage in wider co-operation with R&D institutions, which are capable of creating the scientific foundations of increasingly sophisticated technologies. Apart from examining the relationships between latent variables, soft modelling also helps estimate the values of these variables (weighted sums of indicators). Therefore, for each of the latent variable in the model a synthetic measure is calculated, which can be used to obtain a linear ordering of the analysed objects.

Basing on the values of the synthetic measures of the variables *ITT* and *INN*, and *ED* three rankings of the studied countries were compiled: a ranking of international technology transfer, a ranking of the level of innovation and a ranking of the level of economic development. The results are shown in Table 4.

Table 4. *Values of synthetic measures and rankings of EU countries according to international technology transfer, innovation level, and development level*

Country	***ITT***		***INN***		***ED***	
	Synthetic measure	**Rank**	**Synthetic measure**	**Rank**	**Synthetic measure**	**Rank**
Austria	0.3254	10	1.1419	5	0.8957	5
Belgium	0.8033	7	0.8932	8	1.0609	3
Bulgaria	-1.2975	25	-1.3633	26	-1.7995	27
Croatia	-0.7475	20	-0.9124	21	-1.0177	23

Country	*ITT*		*INN*		*ED*	
	Synthetic measure	**Rank**	**Synthetic measure**	**Rank**	**Synthetic measure**	**Rank**
Cyprus	0.3707	9	-0.5726	18	0.0913	14
Czech Republic	-0.1809	15	-0.1798	13	-0.0240	15
Denmark	1.6565	3	1.1364	6	0.7571	8
Estonia	0.0012	13	-0.2407	14	-0.4432	16
Finland	1.5569	4	1.3368	4	0.4158	11
France	-0.1159	14	0.9041	7	0.8891	6
Germany	-0.6741	18	1.5016	2	0.9528	4
Greece	-0.5773	17	-0.6344	19	-1.1747	25
Hungary	-0.3219	16	-0.3928	16	-0.8460	21
Ireland	1.3396	5	0.7543	9	0.7546	9
Italy	-1.3013	26	-0.2514	15	0.1508	12
Latvia	-0.8808	21	-1.1347	24	-1.1671	24
Lithuania	-0.6856	19	-0.9249	22	-1.0076	22
Luxembourg	1.6961	2	1.4848	3	2.6123	1
Malta	0.0063	12	0.0874	11	0.4530	10
Netherlands	1.1081	6	0.7347	10	1.2191	2
Poland	-0.9080	22	-1.2304	25	-0.5821	20
Portugal	-0.9846	23	-0.4809	17	-0.4926	18
Romania	-1.4422	27	-1.7520	27	-1.6530	26
Slovak Republic	0.0127	11	-1.0304	23	-0.5666	19
Slovenia	0.5130	8	0.0238	12	0.1278	13
Spain	-1.1399	24	-0.6880	20	-0.4507	17
Sweden	1.8678	1	1.7899	1	0.8447	7

The countries were divided into typological groups according to similar levels of international technology transfer (and thus similar innovation levels). The results of the grouping are presented in Figures 2, 3 and 4. The boundaries between the groups were established on the basis of the arithmetic means and standard deviations of the synthetic measure z_i (equal to 0 and 1, respectively, for each of the latent variables). The groups are as follows:

- group I. (very high level of latent variable): $z_i \geq 1$,
- group II. (high level of latent variable): $0 < z_i \leq 1$,
- group III. (low level of latent variable): $-1 < z_i \leq 0$,
- group IV. (very low level of latent variable) $z_i \leq -1$.

Figure 2. *Division of EU countries into typological groups according to international technology transfer in 2008-2017*

Very high international technology transfer was observed in the following countries: Sweden, Luxembourg, Denmark, Finland, Ireland, and Netherland. The group with high international technology transfer comprised seven countries: Belgium, Slovenia, Cyprus, Austria, Slovak Republic, Malta, and Estonia. Ten countries were qualified for the group of economies with medium and low levels of international technology transfer: France, Czech Republic, Hungary, Greece, Germany, Lithuania, Croatia, Latvia, Poland, and Portugal. Four countries were characterised by very low levels of international technology transfer: Spain, Bulgaria, Italy, and Romania.

Countries within the same groups also differ in terms of ITT exploitation. For instance, Luxembourg transfers only technologies associated with financial services, whereas the other countries from the first group resort to other types of transfer (the processing industry, the high-tech industry). In the second group, Slovakia, Slovenia, Malta, Cyprus, and Estonia usually transfer ICT technologies, while in Belgium, it is the service sector that most relies on ITT. The next group contains countries for which ITT is an innovation factor only to a limited extent as their level of development enforces greater involvement in their own innovation activities (France, Germany) and countries whose technological 'underdevelopment' still makes them rely on the purchase of ready-made technologies, but whose production structures constrain the intensity with which new technologies are acquired and implemented. The last group consists of countries at low levels of technical development, at present incapable of absorbing more sophisticated technologies

(Bulgaria, Romania) and those which remain in long-term economic crisis that affects their financial ability to purchase new solutions (Italy, Spain).

Figure 3. *Division of EU countries into typological groups according to the level of innovation in 2008-2017*

Six countries were qualified for the group of economies at very high innovation levels: Sweden, Germany, Luxembourg, Finland, Austria, and Denmark The group of highly innovative economies comprises: France, Belgium, Ireland, Netherlands, Malta, and Slovenia. Group III – countries at medium and low innovation levels – was consisted of: Czech Republic, Estonia, Italy, Hungary, Portugal, Cyprus, Greece, Spain, Croatia, and Lithuania. Low levels of innovation were reported by Slovak Republic, Latvia, Poland, Bulgaria, and Romania.

Among the most innovative economies are those countries where ITT plays a crucial role, although it is the level of R&D expenditure and the scale of innovative investments that is truly decisive. ITT is particularly instrumental for Ireland and Scandinavian countries, where a large proportion of new solutions comes from abroad. In spite of this, these countries do not reduce scientific or research activity, which enables them to dynamically improve their innovation performance. The least innovative countries are incapable of boosting their innovation levels because of the narrow range of their own innovative efforts.

Luxembourg, Netherlands, and Belgium comprise the group of countries with very high economic development. Germany, Austria, France, Sweden, Denmark, Ireland, Malta, Finland, Italy, Slovenia, and Cyprus enjoy high levels of economic development. Czech Republic, Estonia, Spain, Portugal, Slovak Republic, Poland, and Hungary were classified as countries at moderate and low levels of economic development. Six countries: Lithuania, Croatia, Latvia. Greece, Romania, and Bulgaria were found to remain at very low levels of economic development.

The above classification confirms that countries which use ITT to enhance their own innovation attain far better macroeconomic results. Wherever ITT is a per se factor and does not translate into increased innovation, the dynamics of economic development is markedly lower. To sum up, ITT must not merely be used with a view to achieve a simple increase in profits, but should also influence the entire economy through changes in innovation policies or in the R&D activity of economic entities.

Figure 4. *Division of EU countries into typological groups according to the level of economic development in 2008-2017*

6. Conclusions

The article presents the results of empirical studies into the relationships between ITT, innovation and the level of economic development of European Union countries over the years 2008-2017. The research involved developing a soft model, measurement of the latent variables on the basis of sets of observable variables, as well as estimation and verification of the soft model. The outcomes of the modelling reveal a positive influence of international technology transfer and innovation on the level of economic development in the analysed EU countries during the period under review. The influence of innovation proved to be stronger than the impact of ITT. Moreover, the dependence between ITT and the level of innovation was positive as well.

ITT should play a key role in economic development processes, particularly as regards the economies of developing countries, by influencing the character and pace of innovative changes thanks to capital modernisation and altering the structures of production. It should also lead to organisational changes in the structures of economies by necessitating increased concentration of expenditure in high-risk areas and by enabling research and production in new organisational settings. This would facilitate the introduction of innovative activities into the small and medium enterprises sector, leading to the emergence of new competitive structures.

The conducted assessment of the state of innovation in the analysed countries allowed the authors to identify the following major issues associated with ITT implementation:

- ✓ excessively low intensity of innovation – this is one of the syndromes of interconnected problems stemming from limited use of TT, leading to lower productivity and a weakening of international competitiveness;
- ✓ limited internal sources of innovation – investments in R&D and increases in technological capacity are insufficient, especially in the SMEs sector;
- ✓ limited changes in terms of organisation and management – many enterprises fail to take advantage of the possibility to adapt new modes of activity associated with technology and knowledge management;
- ✓ occurrence of a knowledge and experience gap – the number of well-trained employees is limited and the scarcity of pro-innovative activities means that there is no need to train more staff; this is particularly apparent in global companies with rapidly growing knowledge bases, under the conditions of emerging e-commerce markets.
- ✓ necessity to increase the resources of science and technological knowledge – this will help to enhance the capacity for adapting new production, organisational or financing techniques;
- ✓ need for more efficient exploitation of R&D;

Such an influence of ITT on economic development and on the conditions of internal and external competitiveness indicates the growing significance of the microeconomic factors which determine flexibility and innovativeness. It also testifies to the adaptation capabilities of the evolving competitive environment. It follows that by fostering conditions conducive to technological development, thanks to high research and development expenditures, suitable formal and legal infrastructures, and appropriate state policies, EU countries can ensure that both micro- and macroeconomic factors are favourable to innovation in the long term.

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