Journal of Social and Economic Statistics
Vol. 7, No.1, Summer 2018

THE DIFFERENCES OF TECHNOLOGICAL ADVANCE IN EUROPEAN COUNTRIES

Cristina Burlacioiu[a], Andrei Dennis Cruceru[b], Cristina Boboc[c], Constantin Mitrut[d]

Abstract

The emerging of technology and research & development sector is revolutionizing how markets and local economies continuously evolve. Even if there are still wide gaps between European countries in technology, the digital literacy is spread throughout all business in EU market. This paper is aiming to analyze overall technology indicators in CEE region trying to find patterns of R&D areas by using principal component analysis and hierarchical clustering techniques. Twenty eight European countries are analyzed based on Eurostat data regarding digital literacy, high tech areas and research and development investment and engagement. Two main patterns like High Tech foreign trade and R&D focus have been discovered based on these data.

Keywords: Management of Technological Innovation and R&D, principal components analysis, Romania, EU.

JEL Classification: O32, C38

Author's Affiliation

[a] Bucharest University of Economic Studies, Doctoral school: Cybernetics and statistics, cristinaburlacioiu@yahoo.com
[b] Bucharest University of Economic Studies
[c] Bucharest University of Economic Studies, Department of Statistics and Econometrics, cristina.boboc@csie.ase.ro
[d] Bucharest University of Economic Studies, Department of Statistics and Econometrics, cmitrut@ase.ro

1. Introduction

In the present paper we have approached the existence of some possible differences between Romania and other states within the European Union regarding the technological and scientific development (the so-called "Research and Development" or R & D). In the present paper we have identified some technological advances and among them the following: the percentage of renewable energy from the total used, high-tech exports, high-tech imports, the percentage of the total number of dwellings with Internet access and the number of students in the technological fields.

It is desirable to identify the level of technological development for the 28 states within the European Union and to identify the relative position Romania occupies. Developing or advancing technology represents a reduction in production costs for existing goods, an increase in productive efficiency, and an influx of new goods and services. However, the progress of technology is an unpredictable process. It cannot accurately predict what discoveries or innovations will follow.

A first purpose of the paper is to generate an output from which the links between the variables to be analyzed can be seen. This visual representation will be performed using the main principal component analysis.

The second aim of the paper is to obtain a grouping of states within the European Union according to various indicators. Thus, it can be observed the position of Romania together with other states that have similar characteristics, and in this sense a hierarchical classification method, namely the Ward method was used.

2. Literature review

Kafouros (2006) explores the association between the Internet and R&D efficiency. Initially, in order to provide a better unit of analysis, it adopts a feature-based approach to the Internet. Then it offers a conceptual framework which by using theoretical explanations, past empirical research and examples from practice explains how and why two features of the Internet (‘search’ and ‘communication’) improve three critical dimensions of R&D efficiency (cost, time and quality) and a firm's absorptive capacity. Finally, by using the Cobb-Douglas framework, it provides econometric evidence which indicates that the Internet does improve R&D efficiency. Besides the contribution to scholarly knowledge, there are important implications in practice, since the findings of this paper inform decision and policy makers that the Internet has a significant impact on firms' innovative capacity.

Raileanu Szeles (2018) analyzes regional - and country level determinants of the regional digital divide in the EU, based on panel data and using the multilevel analysis- the three level random slope model. The results indicate that only a mix of effective regional and national measures could mitigate the regional digital divide in the EU. Stimulating regional economic growth, increasing the tertiary education attainments, boosting R&D expenditure, and discouraging early leaving from education are regional- and national level policy measures that are found to successfully reduce the regional digital divide in the EU.

Tijssen and Winnink (2018) studied high-income nations and advanced economies finding that the size of R&D expenditure correlates with the sheer size of cited publications, as does the degree of university research cooperation with domestic firms.

Mehrara et al. (2017) analyzed the determinants of export for 24 developing countries during the period 1996 to 2013 based on Bayesian Model Averaging (BMA) and Weighted-Average Least Square (WALS) technique. The results show that rule of law as a proxy for Institutional quality, human capital, import (as a measure of openness) and GDP with posterior inclusion probability 100% are the most important variables influencing the high-technology export in developing countries.

High technology exports and per capita economic growth are also examined in countries with higher levels of technological achievement by Gani (2009). Three groups of countries classified as technological leaders, potential leaders and dynamic adopters are chosen for empirical analysis on the basis of the technological achievement index. The regression results reveal that high technology exports exert a statistically significant positive effect on growth of the technological leader category of countries and a positive but statistically insignificant effect on the potential leader category of countries. The main policy implication is that low-income countries with lower levels of technological achievement and growth may need to focus on new product development with high technological content so as to be competitive in the global trading environment as well as to enhance their growth and development.

3. Countries pattern analysis

Using data collected from the Eurostat website (http://ec.europa.eu/eurostat/data/database), the following 9 variables for the 28 Member States for the year 2015 were chosen:

- Renewable energy: is a quantitative variable expressing the percentage of renewable energy sources in the total used by a state
- High-tech exports: the quantitative variable expressing the percentage of high technology goods in the total export of each state
- High-tech imports: the quantitative variable expressing the percentage of high technology goods in the total imports of each state
- Households Dwellings with Internet access: the percentage variable that represents the share of dwellings with a stable and active connection to the Internet from the total number of dwellings
- The total number of employees in the sectors requiring advanced knowledge: a quantitative variable expressing the number of employees in technological and ICT sectors with a high level of knowledge
- Individuals with a low level of digital literacy: the quantitative percentage variable representing the share of individuals with poor knowledge in the ICT or technological fields
- R & D personnel: the quantitative variable expressing the full-time R & D staff

- Investments in research and development: the quantitative variable representing the level of investment in research and development measured per capita in the Euro
- Students in the technological fields: the quantitative variable representing the total number of students, belonging to any branch of the technological fields.

It can be seen that in the case of the 28 Member States of the European Union the percentage of use of renewable energy sources is about 20%, with a maximum in Sweden (53.8%) and a minimum for Malta (5%). The average percentage of "high-tech" goods exports is 12.25%, which is very close to the average of imports of the same categories of goods, namely 13.22%. Generally, a state will have a higher percentage of imports than exports, but there are some exceptions like: France, Austria and Belgium. This indicates a high level of technological development. For Romania, the percentage of imports and exports of high-tech goods is below average: 7.3% for exports and 10.8% for imports. The percentage of homes with Internet access is, on average, of 80.29%, which suggests a certain integration of technology in society, but not in all countries, given that the minimum is 59% for Bulgaria.

As a number of employees in sectors requiring advanced knowledge, the average is around 7,868, and in this instance, Romania is above average with 8,535 employees.

Table 1: Descriptive statistics based on selected Eurostat indicators

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Percentage of renewable energy in the total used	28	5,00	53,80	19,7964	11,88991	141,370
High Tech Exports	28	3,8	24,2	12,257	6,1809	38,204
High Tech Imports	28	7,2	27,7	13,221	5,1180	26,194
Percentage of total households with Internet access	28	59	97	80,29	9,392	88,212
Total employees in sectors requiring advanced knowledge	28	185,5	40058,0	7868,479	10413,4224	108439365,749
Percentage of individuals with low digital literacy	28	11	35	22,71	4,642	21,545
Research and Dev personnel	28	,0000	2,9213	1,74	,7486023	,560
Research and Dev investment per capita (euro)	28	39,40	1504,30	514,7536	465,55514	216741,589
Students from the technological fields	27	6896	2977781	715651,96	857671,792	735600901948
Valid N (listwise)	27					

Source: Own calculation based on selected Eurostat indicators, reference year 2015, extracted on 05.2018

Individuals with low digital literacy represent a percentage that has declined in recent years as technology is gradually becoming more accessible, more efficient and cheaper. The average of this indicator is 22.71%, with a minimum of 11% for Luxembourg and a maximum of 35% for Ireland.

R&D personnel are expressed as a percentage of the total population and the average is 1.74%, indicating a certain reluctance of the individual towards a research job. This can be correlated with the level of investment per capita in this field, the average of them being about 515 euros.

The number of students in technological fields is another indicator that has a very large variation depending on member state, the average being around 715 thousand, but with a minimum of less than 7 thousand for Luxembourg and a maximum 3 million in the case of Germany. Romania has about 541,000 students in technology, but many of them choose to work in other countries because of more favorable conditions and higher wages. Of course, this trend has a negative impact on the pace of technological advance in Romania.

Based on correlation matrix (Annex 1), the variables that have 3 or more correlation coefficients with a value greater than 0.300 were kept further into analysis: high-tech exports, high-tech imports, the percentage of homes with Internet access, the percentage of low-skilled individuals, R&D personnel, R&D investment per capita.

In the case of high-tech exports, Malta has the highest percentage, namely 24.2%, followed by France with 21.6%. Romania is 21st, with 7.3%, which indicates a relatively low-medium level of technological development.

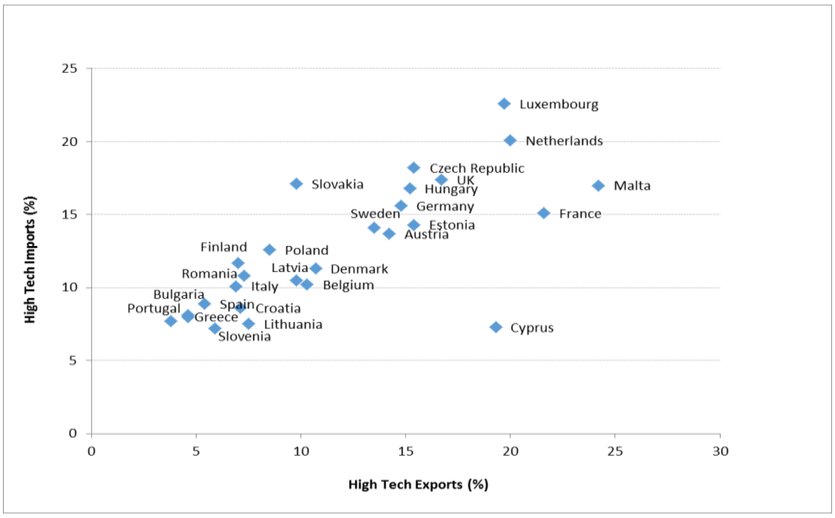


Figure 1: Foreign trade of High Tech products

Source: Own representation based on selected Eurostat indicators, reference year 2015, extracted on 05.2018

Considering high-tech imports, Luxembourg is the country with the highest percentage, namely 22.6%, followed by the Netherlands with 20%. Romania is 18th in this case, with 10.8%.

In general, all countries within the European Union have a higher percentage of imports of high technology goods than exports from the same industry. The only exceptions are Malta, France, Estonia, Austria, Belgium and Cyprus, which indicates a high level of technological development.

Internet access is a very important component that may indicate to some extent the level of development and technological advancement presented by a country and is, by definition, the process of connecting to the Internet through personal computers, laptops or mobile devices by users or businesses.

Internet access is subject to data signaling rates, and users can be connected at different browsing speeds. It allows individuals or organizations to benefit from Internet-based or Internet-based services.

Access is generally provided at home, in schools or workplaces, public places, cafes, libraries. The Internet has grown in popularity through the "dial-up" model, and in a relatively short time, enabling technologies have been upgraded, offering faster and more reliable options. Currently, broadband technologies such as fiber and cable internet or ADSL are widely used methods. The speed, cost, reliability and availability of Internet access depend on the region, provider, and connection type.

There are some distinct ways to get an Internet connection, including: wireless connection, mobile connection, "hotspot", "dial-up", DSL and satellite.

Computer access is one of the most important factors in determining the level of Internet access for a particular region or country. There is a division between countries and regions, and a high-quality connection is generally associated with regions (or countries) with high income populations, a high-growth index, and high-tech development.

Not all countries within the European Union have evolved at the same pace and some have lagged behind in terms of access to the internet. The percentage of homes with Internet access is a variable that best indicates the level of implementation of this technology.

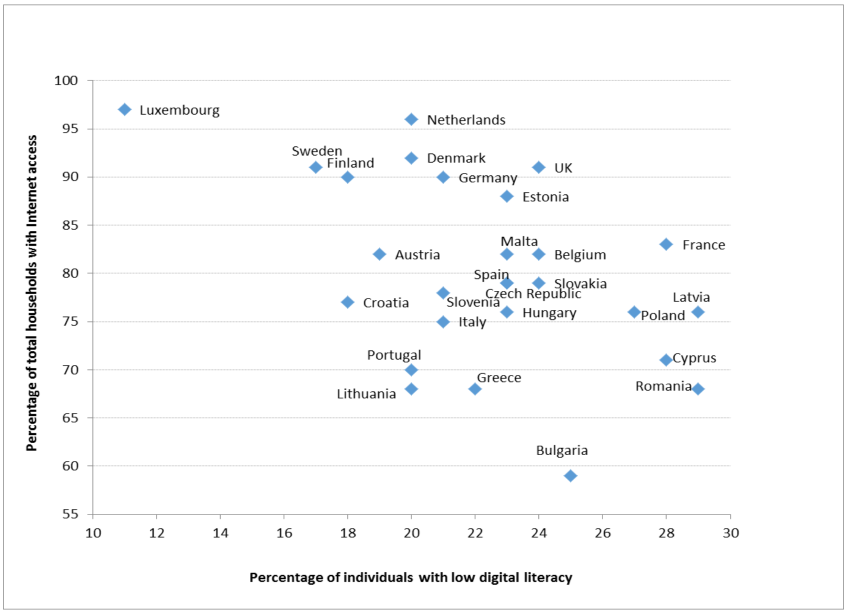


Figure 2: Digital savvy representation

Source data: Own representation based on selected Eurostat indicators, reference year 2015, extracted on 05.2018

Among the countries with the highest percentage of access to the internet in their homes are Luxembourg, the Netherlands, Denmark and the United Kingdom. Romania has a percentage below 70%, which places it below the 80% average.

However, the average Internet connection speed should not be omitted, because Romania is in the lead position with other countries. It is also important to note that the majority of countries have a percentage of over 65%, with the only exception being Bulgaria with 59%.

Surprisingly, France is the country among the ones with the highest rate of low digital literacy alongside Latvia, Romania and Cyprus.

Considering research and development indicators, it is shown that there is a clear distinction between a group of countries that invest consistently into research and development area with investments higher than 600 Eur per capita and weight of personnel working in this field around 2,5% and the other group of countries that invests under 400 Eur per capita and the personnel employed into R&D under 2%.

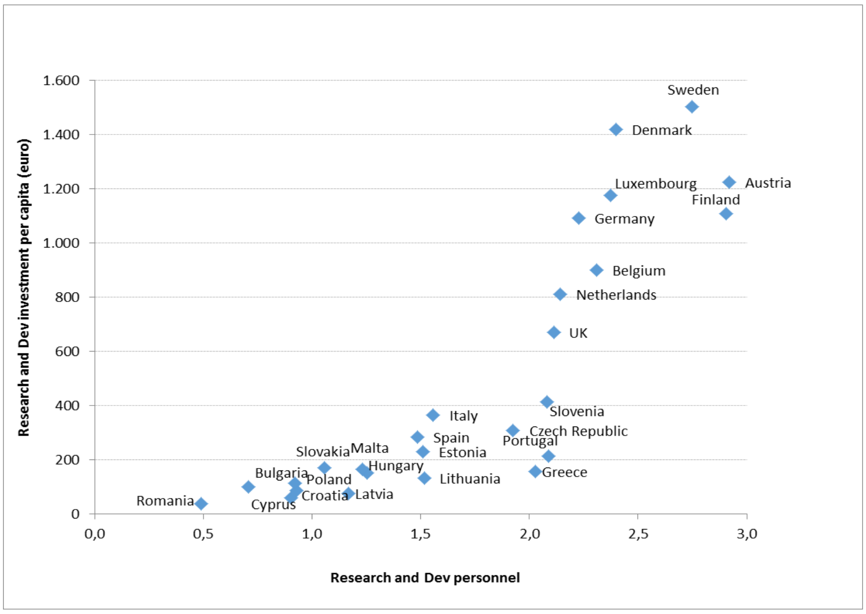


Figure 3: Research and Development – Investment (Eur) & personnel (%)

Source data: Own representation based on selected Eurostat indicators, reference year 2015, extracted on 05.2018

Principal component analysis (PCA) is used to reduce the complexity of the data and to present the information on fewer dimensions when all the variables are quantitative. It is mathematically defined as an orthogonal linear transformation that projects the data to a new coordinate system (which is made by principal components) in order to obtain the greatest variance explained by this projection of the data.

Table 2: Component matrix on PCA

Component Matrix[a]

	Component	
	1	2
Percentage of total households with Internet access	,929	,068
Research and Dev investment per capita (euro)	,866	-,263
Research and Dev personnel	,716	-,507
High Tech Exports	,573	,738
High Tech Imports	,681	,620
Percentage of individuals with low digital literacy	-,443	,718

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Source data: Own calculation based on selected Eurostat indicators, reference year 2015, extracted on 05.2018

By applying this method the projection of data on the first two principal components preserves 81.5% of the total inertia (51.9% for the first axis and 29.6% for the second axis).

On the first axis, the best represented variables on are the ones regarding R&D (Internet access, R&D investments and R&D personnel). The second axis could be called the axis of foreign trade because it accounts for exports and imports of high tech and at the same time the lowest level of digital literacy.

The variables included in the analysis will be represented in the correlation circle of radius 1, where the direct link between them and the way each influences the two main components.

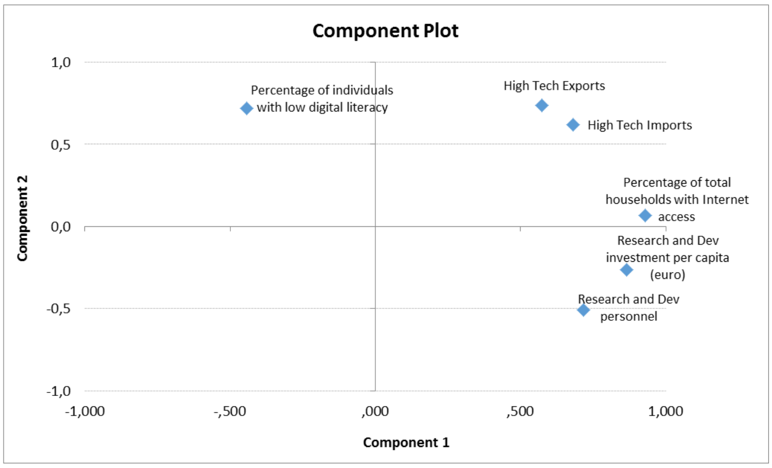


Figure 4: Component plot

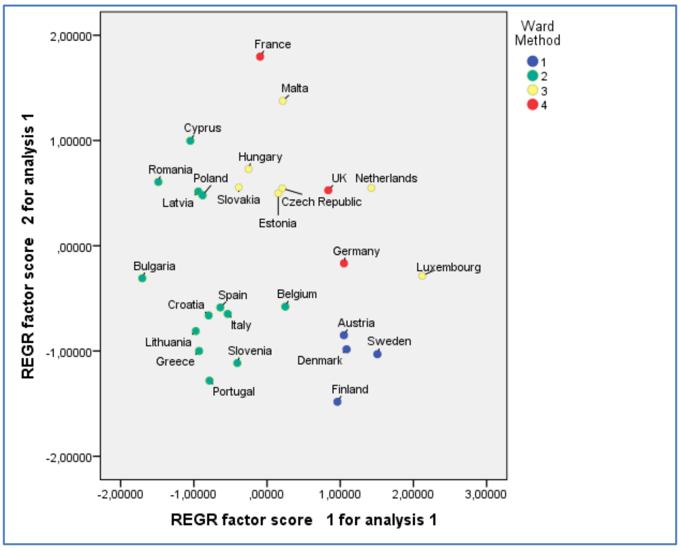
Source data: Own representation based on selected Eurostat indicators, reference year 2015, extracted on 05.2018

From the previous graph it can be seen where each variable is placed in the correlation circle and whose components exert more influence.

• Axis OX: there is a strong and positive correlation between investment in R&D per capita and R&D personnel, and these two variables positively influence component 1. Also, the percentage of households with Internet access has an influence on the component 1, since its position on the graph is very close to the axis. Another strong and positive correlation exists between "high-tech" imports and exports;

• Axis OY: is influenced to a certain extent by the percentage of individuals with low digital literacy and also foreign trade with high tech products.

Classification requires the formation of clusters (or clusters) of statistical units according to the degree of similarity between them, taking into account the characteristics to be studied. The hierarchical classification method seeks to obtain more agglomerations in size and as homogeneous as possible. Ward's varied hierarchical classification method evaluates the distances between two agglomerations and is based on maximizing class variability and minimizing variability within classes.



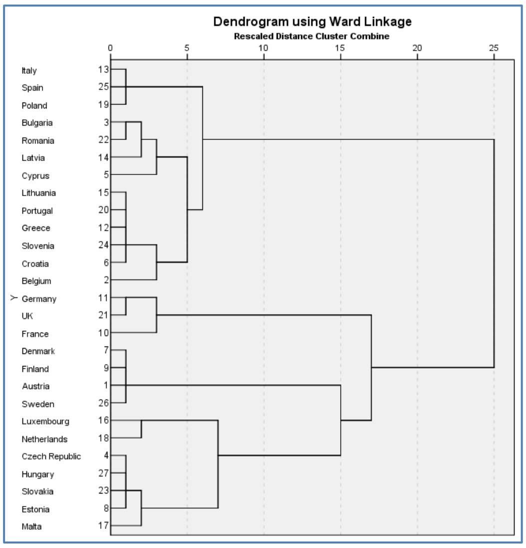


Figure 5: Projection of countries on the first two principal components

Figure 6: Dendrogram on Ward clustering

Source data: Own representation based on selected Eurostat indicators, reference year 2015, extracted on 05.2018

By applying this technique on existent data 4 clusters could be defined. First cluster contains 4 countries: Austria, Sweden, Denmark and Finland with medium High tech foreign trade but the highest weight of digital literacy in population and the highest level of research and development indicators (high values for investment in R&D and personnel employed within R&D sector). The second cluster is made 13 countries, including Romania that score lowest on the first component of principal components reduction, namely on R&D indicators and percentage of households with internet access. The third cluster is made by 7 countries (Czech Republic, Estonia, Hungary, Slovakia, Malta, Netherlands, Luxembourg) that have the highest level on High Tech foreign trade and medium on the first component with the exception of Netherlands and Luxembourg. France, UK and Germany are part of the fourth cluster as having all indicators on high levels.

Some of the Member States are located around the intersection of the two main components, indicating that they have average values for the variables describing the axes. Examples are: Belgium, Italy, Spain, Estonia, Slovakia and Poland.

In the case of Romania, this shows a very high percentage of individuals with a low level of digital knowledge and with low investment into research and development area. On the graph, it is relatively far from the intersection of the two axes, suggesting a move away from the average.

4. Conclusions

The advanced technology pattern of European countries is very much based on research and development attributes (investment and personnel working in R&D area), digital savvy (access to Internet and level of digital literacy) and foreign trade of high tech products (exports and imports). These 6 factors were grouped through PCA into 2 factors: one characterized by R&D and level of Internet access and the other one characterized by high tech foreign trade and digital literacy. Countries like Austria, Sweden, Denmark and Finland are very well highlighted trough their strong focus into R&D and their exceptional level of digital literacy. Their moderate presence into high-tech foreign trade may be translated into a push for national economy to sustain high tech demand and keep it nationally as the current development sustains it.

Based on the analysis, Romania is the country with the lowest focus on research and development, almost the lowest level of digital savvy (Bulgaria is the lowest) and the country between the ones with low level of high-tech foreign trade. Romania should follow the example of these 4 countries and to focus more on research and development as this is the key to the technology advance. More easily target to reach is to improve the digital savvy component through increasing the internet penetration, moreover that the internet connection that Romania provides is the one of extremely high quality in the entire world and also cheap.

References

- Kafouros, M. (2006). The impact of the Internet on R&D efficiency: theory and evidence. *Technovation*, **26**(7), July 2006, pp. 827-835.
- Gani, A. (2009). Technological Achievement, High Technology Exports and Growth. *Journal of Comparative International Management*, **12**(2), pp. 31-47.
- Mohsen Mehrara, M., Seijani, S., Abbas Rezazadeh Karsalari, A. (2017). Determinants of high-tech export in developing countries based on Bayesian model averaging. *Zb. rad. Ekon. fak. Rij.*, **35**(1), pp. 199-215.
- Raileanu Szeles, M. (2018). New insights from a multilevel approach to the regional digital divide in the European Union. *Telecommunications Policy*, **42** (6), pp. 452-463.
- Sandu, S., Ciocanel, B. (2014). Impact of R&D and Innovation on high - tech export. *Procedia Economics and Finance*, **15**, pp. 80 – 90.

- Tebaldi, E. (2011). The Determinants of High-Technology Exports: A Panel Data Analysis. *Atlantic Economic Journal*, **39**(4), pp. 343–353.
- Tijssen, R., Winnink, J. (2018). Capturing 'R&D excellence': indicators, international statistics, and innovative universities. *Scientometrics*, **114**(2), pp. 687–699.
- Vitola, L., Erina, J. (2015). *R&D expenditures by higher education sector and analysis of performance indicators of Baltic States.* 20th International Scientific Conference Economics and Management - 2015 (ICEM-2015). Procedia - Social and Behavioral Sciences, **213** (2015), pp. 223 – 228.

Annexe 1 Correlation matrix between considered variables

Correlations

		Percentage of renewable energy in the total used	High Tech Exports	High Tech Imports	Percentage of total households with Internet access	Total employees in sectors requiring advanced knowledge	Percentage of individuals with low digital literacy	Research and Dev personnel	Research and Dev investment per capita (euro)	Students from the technological fields
Percentage of renewable energy in the total used	Pearson Correlation	1	-,418*	-,382*	-,010	-,237	-,250	,263	,257	-,271
	Sig. (2-tailed)		,027	,045	,960	,224	,200	,176	,187	,171
	N	28	28	28	28	28	28	28	28	27
High Tech Exports	Pearson Correlation	-,418*	1	,773**	,553**	,079	,184	-,001	,292	,087
	Sig. (2-tailed)	,027		,000	,002	,689	,348	,996	,131	,666
	N	28	28	28	28	28	28	28	28	27
High Tech Imports	Pearson Correlation	-,382*	,773**	1	,626**	,095	,099	,221	,347	,139
	Sig. (2-tailed)	,045	,000		,000	,632	,616	,258	,071	,489
	N	28	28	28	28	28	28	28	28	27
Percentage of total households with Internet access	Pearson Correlation	-,010	,553**	,626**	1	,203	-,369	,546**	,767**	,194
	Sig. (2-tailed)	,960	,002	,000		,299	,053	,003	,000	,331
	N	28	28	28	28	28	28	28	28	27
Total employees in sectors requiring advanced knowledge	Pearson Correlation	-,237	,079	,095	,203	1	,105	-,090	,177	,980**
	Sig. (2-tailed)	,224	,689	,632	,299		,596	,647	,368	,000
	N	28	28	28	28	28	28	28	28	27
Percentage of individuals with low digital literacy	Pearson Correlation	-,250	,184	,099	-,369	,105	1	-,527**	-,448*	,206
	Sig. (2-tailed)	,200	,348	,616	,053	,596		,004	,017	,303
	N	28	28	28	28	28	28	28	28	27
Research and Dev personnel	Pearson Correlation	,263	-,001	,221	,546**	-,090	-,527**	1	,718**	-,094
	Sig. (2-tailed)	,176	,996	,258	,003	,647	,004		,000	,642
	N	28	28	28	28	28	28	28	28	27
Research and Dev investment per capita (euro)	Pearson Correlation	,257	,292	,347	,767**	,177	-,448*	,718**	1	,173
	Sig. (2-tailed)	,187	,131	,071	,000	,368	,017	,000		,387
	N	28	28	28	28	28	28	28	28	27
Students from the technological fields	Pearson Correlation	-,271	,087	,139	,194	,980**	,206	-,094	,173	1
	Sig. (2-tailed)	,171	,666	,489	,331	,000	,303	,642	,387	
	N	27	27	27	27	27	27	27	27	27

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Source data: Own computations based on Eurostat Database