



TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 65, Issue III, September, 2022

REACHING INDUSTRY 4.0 GOALS UNDER THE INFLUENCE OF SUSTAINABLE FINANCE

Laura-Nicoleta COVACIU, Florin COVACIU, Laura BACALI

Abstract: Using official EU data for 7 countries in the Central and Eastern Europe (CEE) area, this study analyzed the influence of sustainable finance on reaching the objectives of Industry 4.0. The results obtained allow us to state that sustainable finance (represented by green finance) has the potential to contribute to the improvement of indicators that reflect the transition to Industry 4.0 in CEE countries. Thus, sustainable finance has the potential to support digital performance, can promote innovations, has the potential to contribute to human capacity development, and can support sustainable development. In CEE countries, sustainable finance represents a still small share in the mix of available financing sources, but the results obtained reveal that sustainable finance is likely to play a much greater role in supporting innovative Industry 4.0 projects in the coming period.

Key words: Industry 4.0, Sustainable finance, Sustainable bonds, Green bonds, Digital performance, Innovation, Human development, Sustainable development.

1. INTRODUCTION

Industry 4.0 is the generic term given to that segment of the industry that has innovation at the forefront and which is based mainly on technological development.

According to official reports, the European Commission reveals that EU countries are lagging behind countries such as China, Japan and the USA in terms of technological advance. Moreover, important differences are also observed within the EU, with Central and Eastern European (CEE) countries being at the bottom of the rankings in terms of innovation and technological development [1,2]. Being aware of the situation, European officials are trying to find a solution and one of the solutions brought up was to increase investments in technology. On the other hand, another important concern of the European Commission refers to sustainable finance, given the major risks identified due to global warming. Thus, the question was raised to what extent sustainable finance can support the reduction of differences

between countries in terms of technological advance.

In view of these considerations, this study aimed to identify the potential of sustainable finance to contribute to the improvement of indicators reflecting the transition to Industry 4.0 in CEE countries. From the very beginning, we mention that no study has been identified to highlight the issue of sustainable finance in the context of the objectives of Industry 4.0.

2. THEORETICAL BACKGROUND

Over time, the economy has gone through several industrial revolutions. The widespread use of steam engine, electricity and information and communication technologies in many sectors of activity has facilitated the development of other new innovations that affect the entire economy [3].

Industry 4.0 or the fourth industrial revolution is a sustainable foundation for innovation and technological development, mainly referring to the Internet of Things (IoT),

Artificial Intelligence (AI), machine learning and cyber-physical systems [4].

Industry 4.0 includes digital technologies (such as industrial robots, 3D printing), new materials (such as biomaterials or nanomaterials) and processes (aimed at spreading the use of big data). Industrial robots are increasingly used in industrial automation. [5,6]. These robots are engaged in performing repetitive and/or work tasks that require high accuracy and speed, impossible for human beings to achieve, thus leading to production efficiency and improved product quality. Because of this, robots have revolutionized the industrial manufacturing process [7,8].

Current studies have highlighted the importance of the link between the concept of Industry 4.0 and sustainability, stating that Industry 4.0 will play an increasingly important role in advancing sustainable development [9,10]. In this context, it is very important for managers to understand their impact on sustainability from the perspective of the environmental, social and economic dimension [11]. Sustainable development contributes to achieving the objectives of the circular economy in terms of environmental, economic and social benefits [12,13].

In the context of Industry 4.0, technological changes brought about by organizational and cultural priorities can bring about changes in supply chains. In this respect, the aim is to create more sustainable networks to serve customers and support responsible decisions in the supply lifecycle [14,15].

Digital technologies can improve the activities of workers in the manufacturing industry in terms of super-strength capability, augmented capability, virtual capability, healthy capability, smart capability, collaborative, social capability, analytical capability [16]. However, the transition to Industry 4.0 can pose a challenge for businesses from the perspective of the associated risks, such as: lack of standards and lack of methodological approaches, lack of talent, uncertainty about economic benefits, and possible delay in production [17]. In terms of technical skills, companies need to allocate resources for professional training and retraining of staff [18]. In this context, companies find

themselves in a position to redesign their business models, adopting business models centred on novelty and innovation [19].

Over the past decade, some EU countries have taken important steps towards adopting Industry 4.0 technologies. However, Romania must continue to adapt its transition strategy to Industry 4.0, given the need to protect the environment, to find solutions to social and economic problems, and to make more efficient use of resources [20].

Industry 4.0 involves the use of advanced technologies and artificial intelligence to connect installations, processes, products and people. In order to advance this transformation, industrial companies need very large amounts of capital. The bank financing is one of the important factors responsible for technological innovation in the G7 countries. However, the high cost of innovation requires other financing solutions to be found [21]. Given the recent concerns regarding sustainable finance, the question arises to what extent this type of financing can present resources to help companies in this direction of transaction to Industry 4.0.

3. SUSTAINABLE FINANCE

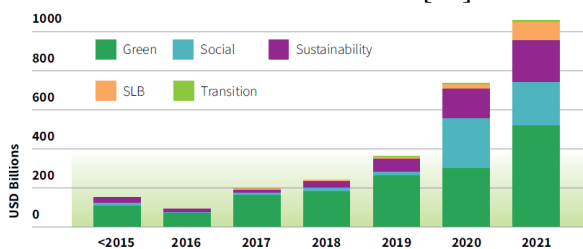
In view of the major risks identified due to global warming, the European Commission is committed to taking the necessary measures to reduce greenhouse gas emissions to zero by 2050. In this context, major changes in the economies are expected to occur, while creating important challenges for some sectors of activity.

In all this, sustainable finance is an important concern of the European Commission, having a key role to play in meeting climate and sustainability objectives and commitments. Thus, sustainable finance is valued as the kind of financing that contributes to the sustainable development of the economy, while reducing pressures on the environment and taking into account social and governance aspects.

Sustainable finance refers to integrating environmental, social or governance criteria into financial services and supporting sustainable economic growth. Sustainable bonds are the most representative form of sustainable finance.

Sustainable bonds are fixed income financial instruments that are used to finance projects that have positive environmental and/or climate benefits [22].

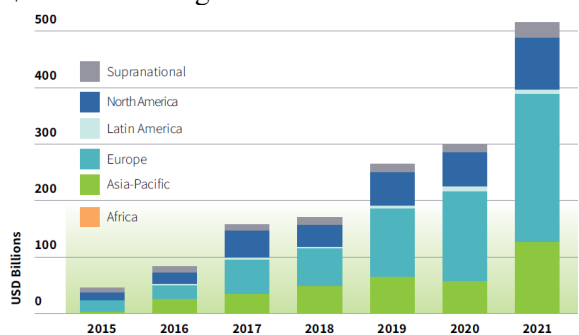
Globally, sustainable bonds have seen an important growth in recent years, both from the perspective of green, social and sustainability bonds and from the perspective of sustainability-linked bonds and transition bonds [23].



Source: Climate Bonds Initiative
Fig. 1. The evolution of sustainable finance [23]

Given the significant share that green bond represents in the total sustainable debt instruments (in 2021 it accounted for 49% of the total), we consider this instrument to be the most representative of the sustainable bonds category, which is why we will continue to focus our attention on its research.

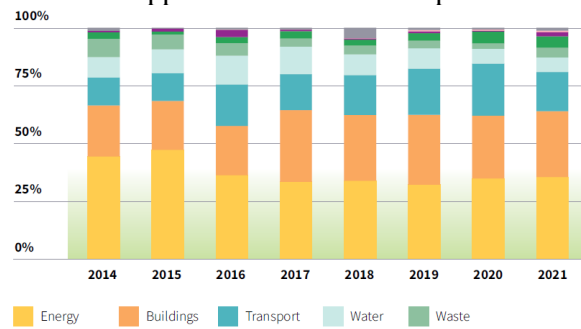
Geographically, half of the green bond volumes come from Europe, contributing \$265 billion. The second most important source of green bonds is the Asia-Pacific region, the most representative countries for this region being China, Japan and Singapore. North America ranked third with the cumulative issuance of \$343 billion of green bonds.



Source: Climate Bonds Initiative
Fig. 2. Green Bond volumes by Region [23]

From the use of proceeds perspective, the energy sector, buildings, and transport are the three main categories, together accounting for 81% of the total in 2021. The energy and

transport sectors were supported by non-financial corporate, while the construction sector received support from financial corporates.



Source: Climate Bonds Initiative
Fig. 3. Use of Proceeds [23]

In Romania, the green finance sector is at an early stage, encountering a number of obstacles related to data availability, transparency, lack of regulation or best practice guides, lack of a relevant risk assessment, and other obstacles. However, in 2021, Raiffeisen Bank was the first bank in Romania to issue green bonds, the total amount of the issue being EUR 81 million.

4. RESEARCH METHODOLOGY AND RESULTS

In order to demonstrate the impact of sustainable finance (represented by sustainable bonds) on supporting the deployment of Industry 4.0 technologies and skills, we evaluated this impact by conducting a study. This study is based on a sample of data from 7 CEE countries (Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovenia), valid for the period 2015-2020. We selected these countries because they were the only countries in this region to issue sustainable bonds during the mentioned period.

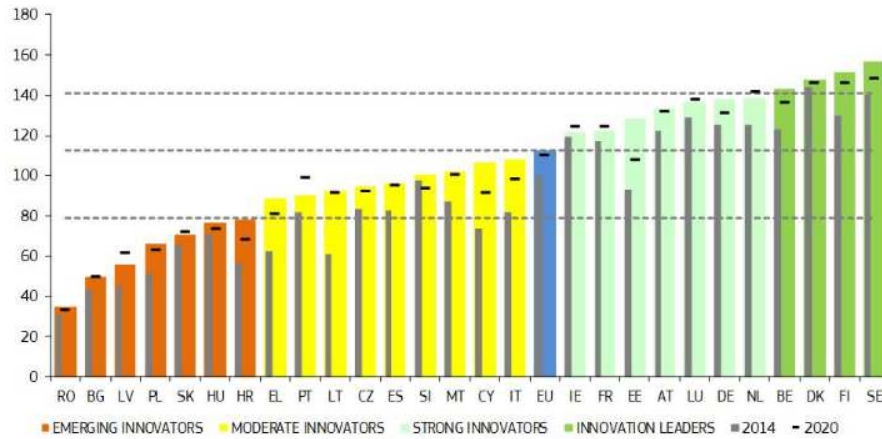
The following variables were considered in the study:

Green bonds amount issued as a percentage of GDP (GB). This indicator represents the total amount of green bonds issues reported as a percentage of GDP.

Innovation Index - Use of information technologies (EIS). Based on the European Innovation Scoreboard, this indicator reflects research and innovation performance and the use of information technologies.

In terms of innovation, according to the latest data published by the European Commission in the European Innovation Scoreboard, Romania is in the last category, that of Emerging

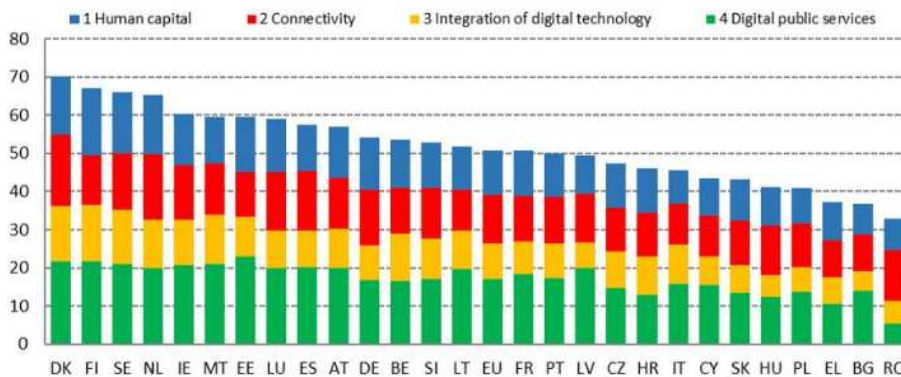
innovators, with other CEE countries in this category [24].



Source: EIS 2021, European Commission
Fig. 4. European Innovation Scoreboard [24]

The Digital Economy and Society Index (DESI) is an index reflecting Europe’s digital performance, following the evolution of EU Member States across five main dimensions: Human capital (DESIH), Connectivity (DESIC), Integration of Digital Technology (DESII),

Digital Public Services (DESID), Internet usage. In 2021, DESI ranged between 33 in Romania and 70 in Denmark, with an EU average of 51 [25]. The graphical representation of the main dimensions is shown in Figure 7.



Source: DESI 2021, European Commission
Fig. 5. Digital Economy and Society Index 2021 ranking [25]

The Human Development Index (HDI) is a composite index that measures achievements from a human development perspective. The main components of this index relate to: a long and healthy life, access to knowledge and education, a decent standard of living. In 2019, in EU countries, HDI ranged from 0.816 in Bulgaria to 0.957 in Norway [26].

The Sustainable Development Index (SDG) is an assessment of each country’s

overall performance in terms of 17 objectives: No poverty, Zero hunger, Good health and well-being, Quality education, Gender equality, Clean water and sanitation, Affordable and clean energy, Decent work and economic growth, Industry, innovation and infrastructure, Reduced Inequalities, Sustainable cities and communities, Responsible consumption and production, Climate actions, Life below water, Life and land, Peace, justice and strong institutions,

Partnerships for the goals. Each objective is given an equal weighting and the score means a country's position between 0 (worst result) and 100 (target result). In 2021, in the EU countries, SDG ranged from 73.8 in Bulgaria to 85.9 in Finland [27].

To analyze the correlations between green bonds, and the indicators of digital performance, innovation, human development and sustainable development, we estimated the econometric models below.

$$DESI = \alpha + \beta_1 \cdot GB_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$DESIH = \alpha + \beta_1 \cdot GB_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$DESIC = \alpha + \beta_1 \cdot GB_{i,t} + \varepsilon_{i,t} \quad (3)$$

$$DESID = \alpha + \beta_1 \cdot GB_{i,t} + \varepsilon_{i,t} \quad (4)$$

$$DESII = \alpha + \beta_1 \cdot GB_{i,t} + \varepsilon_{i,t} \quad (5)$$

$$EIS = \alpha + \beta_1 \cdot GB_{i,t} + \varepsilon_{i,t} \quad (6)$$

$$HDI = \alpha + \beta_1 \cdot GB_{i,t} + \varepsilon_{i,t} \quad (7)$$

$$SDG = \alpha + \beta_1 \cdot GB_{i,t} + \varepsilon_{i,t} \quad (8)$$

where:

DESI - Digital Economy and Society Index, dependent variable i= country, t= year;

DESIH - Human capital, dependent variable i= country, t= year;

DESIC - Connectivity, dependent variable i= country, t= year;

DESID - Digital Public Services, dependent variable i= country, t= year;

DESII - Integration of Digital Technology, dependent variable i= country, t= year;

EIS - Innovation Index, dependent variable i= country, t= year;

HDI - Human Development Index, dependent variable i= country, t= year;

SDG - Sustainable Development Index, dependent variable i= country, t= year;

α - the constant term of the regression model;

β_1 - independent variable coefficient;

$GB_{i,t}$ - Green bonds amount issued as a percentage of GDP, independent variable, i= country, t= year;

$\varepsilon_{i,t}$ - the error term.

In order to validate econometric models, a number of statistical tests have been carried out.

As the sample consists of data in the panel structure, the selection of the type of fixed or random effects was made on the basis of the Hausman test. If the probability associated with

the test is higher than 5 %, the null hypothesis is accepted, according to which the corresponding model uses random effects.

The testing of the lack of multicollinearity is verified by calculating the Variance Inflation Factor (VIF) indicator. If the Centered VIF value is less than 10, then multicollinearity is not a problem.

The testing of the normality of errors is carried out using the Jarque-Bera test. If the probability associated with this test is above 5%, the null hypothesis is accepted, according to which the errors are normally distributed.

Homoscedasticity testing is carried out by means of the White test. If Prob. Chi-Square is above 5%, the null hypothesis that the variance of errors is constant is accepted.

The validity of the model is checked using F-Test. If Prob (F-Statistic) is below the significance value of 5%, it can be said that the model is valid.

The results of estimates of econometric models (1) to (8) are presented in Tables 1 to 8.

Table 1
Results of regression analysis of dependence
DESI(GB)

Regression statistics	Values
R-squared	0.171
F-statistic	8.225
Prob(F-statistic)	0.007
Jarque-Bera	0.364
Jarque-Bera Probability	0.833
VIF	1.206
Prob. Chi-Square (Heteroskedasticity Test)	0.622
Prob. Cross-section random	0.668
Observations	42

Variables	Coefficient	Std. Error	t-Statistic	Prob.
C	40.740	2.628	15.505	0
GB	4.717	1.662	2.839	0.0071

Source: author's processing

As can be seen from the table above, the probability associated with F-Test "Prob(F-statistical)" is 0.007, below the level of significance of 5%, so it can be said that the model is valid. The value indicated by the coefficient of determination (R^2) indicates that 17.1% of the variation of the dependent variable (DESI) is explained by the model. The probability associated with the Hausman test

(0.668) indicates the choice of random effects. Also, the probability associated with the Jarque-Bera test of 0.833, above 5%, shows that the errors are normally distributed. As found, VIF is below 10, so multicollinearity is not a problem. Prob. Chi-Square, associated with the White test, is 0.622, above 5%, thus accepting the null hypothesis that the variance of errors is constant.

The link between the indicators is direct (estimated value of the coefficient is 4.717).

Therefore, from the analysis of the results presented in Table 1, we find that green bonds have a statistically significant influence on the Digital Economy and Society Index. By increasing the value of green bonds amount issued as a percentage of GDP by one unit, the Digital Economy and Society Index can be increased from 41.80 points to 45.46 points (by 8.74%).

Jarque-Bera Probability	0.716
VIF	1.390
Prob. Chi-Square (Heteroskedasticity Test)	0.539
Prob. Cross-section random	0.881
Observations	42

Variables	Coefficient	Std. Error	t-Statistic	Prob.
C	9.322	0.475	19.624	0
GB	1.832	0.470	3.901	0.0004

Source: author's processing

The results presented in Table 3 reveal that, green bond has a statistically significant influence on the Connectivity dimension. Since Prob(F-Statistic)=0.000 (<0.05), VIF<10, Prob. Jarque-BeraTest>0.05, Prob. Chi-Square>0.05, it can be said that the regression model is valid. The link between the indicators is direct (1.832), 28.1% of the change in the dependent variable (DESIC) is explained by the change in the independent variable (R²=0.281). By increasing the value of green bonds amount issued as a percentage of GDP by one unit, the Connectivity Index can be increased from 9.74 points to 11.15 points (by 14.57 %).

Table 2

Results of regression analysis of dependence DESIH(GB)

Regression statistics	Values
R-squared	0.060
F-statistic	2.573
Prob(F-statistic)	0.117
Jarque-Bera	2.917
Jarque-Bera Probability	0.233
VIF	1.064
Prob. Chi-Square (Heteroskedasticity Test)	0.920
Prob. Cross-section random	0.656
Observations	42

Variables	Coefficient	Std. Error	t-Statistic	Prob.
C	10.785	0.601	17.956	0
GB	0.282	0.178	1.588	0.1202

Source: author's processing

Given the results obtained in Table 2, we could not establish a statistically significant link between green bonds and the Human Capital dimension. The probability associated with F-Test, "Prob(F-statistics)" of 0.117 above the significance value of 5%, indicates that the regression model is not valid.

Table 3

Results of regression analysis of dependence DESIC(GB)

Regression statistics	Values
R-squared	0.281
F-statistic	15.601
Prob(F-statistic)	0.000
Jarque-Bera	0.668

Table 4

Results of regression analysis of dependence DESID(GB)

Regression statistics	Values
R-squared	0.134
F-statistic	6.197
Prob(F-statistic)	0.017
Jarque-Bera	2.269
Jarque-Bera Probability	0.322
VIF	1.155
Prob. Chi-Square (Heteroskedasticity Test)	0.779
Prob. Cross-section random	0.470
Observations	42

Variables	Coefficient	Std. Error	t-Statistic	Prob.
C	13.930	1.426	9.769	0
GB	1.676	0.677	2.475	0.0177

Source: author's processing

According to the data presented in Table 4, green bond has a statistically significant influence on Digital Public Services dimension. As a result of the statistical tests, the following values were obtained: Prob(F-Statistic) = 0.017 (<0.05), VIF<10, Prob. Jarque-BeraTest=0.322 (>0.05), Prob. Chi-Square=0.779 (>0.05). By obtaining these results it can be said that the

regression model is valid. The link between the indicators is direct (1.676), 13.4% of the change in the dependent variable (DESID) is explained by the change in the independent variable ($R^2=0.134$). By increasing the value of green bonds amount issued as a percentage of GDP by one unit, the Digital Public Services Index can be increased from 14.31 points to 15.61 points (by 9.07%).

Table 5

Regression statistics	Values
R-squared	0.116
F-statistic	5.225
Prob(F-statistic)	0.028
Jarque-Bera	2.329
Jarque-Bera Probability	0.312
VIF	1.131
Prob. Chi-Square (Heteroskedasticity Test)	0.690
Prob. Cross-section random	0.742
Observations	42

Variables	Coefficient	Std. Error	t-Statistic	Prob.
C	6.700	0.760	8.821	0
GB	0.964	0.427	2.260	0.0293

Source: author's processing

The probability associated with F-Test "Prob(F-statistics)" is 0.028, below the level of significance of 5%. The probability associated with the Hausman test (0.742) indicates the choice of random effects. Also, the probability associated with the Jarque-Bera test of 0.312, above 5%, shows that errors are normally distributed. Prob. Chi-Square, associated with the White test, is 0.69, above 5%, thus accepting the null hypothesis that the variance of errors is constant. VIF is below 10, so multicollinearity is not a problem. By obtaining these results, it can be said that the regression model is valid and that green bond has a statistically significant influence on the Integration of Digital Technology dimension. The link between the indicators is direct (0.964), 11.6 % of the change in the dependent variable (DESII) is explained by the change in the independent variable ($R^2=0.116$). By increasing the value of green bonds amount issued as a percentage of GDP by one unit, the Integration of Digital Technology Index can be increased from 6.92 points to 7.66 points (by 10.79%).

Table 6

Results of regression analysis of dependence EIS(GB)

Regression statistics	Values
R-squared	0.098
F-statistic	4.363
Prob(F-statistic)	0.043
Jarque-Bera	3.156
Jarque-Bera Probability	0.206
VIF	1.109
Prob. Chi-Square (Heteroskedasticity Test)	0.696
Prob. Cross-section random	0.800
Observations	42

Variables	Coefficient	Std. Error	t-Statistic	Prob.
C	88.219	14.364	6.142	0
GB	8.279	4.011	2.064	0.0455

Source: author's processing

From the data presented in Table 6, it can be concluded that green bonds have a statistically significant influence on the Innovation Index - "Use of information technologies indicator". The regression model is valid, given that: Prob(F-Statistic) = 0.043 (<0.05), VIF<10, Prob. Jarque-BeraTest>0.05, Prob. Chi-Square>0.05. The link between indicators is direct (8.279), 9.8% of the change in the dependent variable (EIS) is explained by the change in the independent variable ($R^2=0.098$). By increasing the value of green bonds amount issued as a percentage of GDP by one unit, the Innovation Index can be increased from 90.09 points to 96.50 points (by 7.12%).

Table 7

Results of regression analysis of dependence HDI(GB).

Regression statistics	Values
R-squared	0.118
F-statistic	4.395
Prob(F-statistic)	0.044
Jarque-Bera	1.703
Jarque-Bera Probability	0.427
VIF	1.133
Prob. Chi-Square (Heteroskedasticity Test)	0.295
Prob. Cross-section random	0.224
Observations	35

Variables	Coefficient	Std. Error	t-Statistic	Prob.
C	0.869	0.008	114.990	0
GB	0.011	0.005	2.112	0.0424

Source: author's processing

From the results presented in Table 7, we draw the conclusion that, green bonds have a

statistically significant influence on the Human Development Index. The following values demonstrate that the econometric model is valid: Prob(F-Statistic) = 0.044 (<0.05), VIF<10, Prob. Jarque-Bera Test>0.05, Prob. Chi-Square>0.05. The link between the indicators is direct (0.011), 11.8% of the change in the dependent variable (HDI) is explained by the change in the independent variable ($R^2=0.118$). By increasing the value of green bonds amount issued as a percentage of GDP by one unit, the Human Development Index can be increased from 0.87 points to 0.88 points (by 1.07%).

development. However, this influence is not very high given the values of R^2 .

5. CONCLUSIONS

Aiming to show if sustainable finance can make a contribution to supporting the implementation of technologies and the competencies of Industry 4.0. in CEE countries, we have formulated the research objective mentioned in the first part of this study. As part of this approach, we have sought to determine the extent to which sustainable finance contributes to the improvement of indicators that relate to digital performance, innovation, human development and sustainable development. In the study we used the sustainable bond variable through green bond, given that this is the most representative form of sustainable finance in CEE countries.

The results obtained, following the econometric analysis carried out on the basis of official data from 7 CEE countries, show us that green bonds have a statistically significant influence on the Digital Economy and Society Index (DESI) indicator, as well as on the three main dimensions: Connectivity (DESIC), Digital Public Services (DESID), Integration of Digital Technology (DESII). A statistically significant link could not be established between the Human Capital (DESIH) dimension and green bonds. Regarding the relationship of green bonds with the Human Development Index (HDI) and the Sustainable Development Index (SDG), it has been shown that a higher share of green bonds is associated with a higher score of these indicators. So, we've proven that green bonds exert a statistically significant influence on indicators that reflect adaptation to Industry 4.0 in these countries. However, at the moment, its influence is not a major one.

In the light of these results, it can be appreciated that an increase in green bonds in the economies of CEE countries can lead to a faster recovery of technological differences.

Regression analysis has led to results that allow us to say that sustainable finance (through green bond) has the potential to support digital performance in CEE countries. To the same extent, sustainable finance can promote innovation, have the potential to contribute to

Table 8
Results of regression analysis of dependence
SDG(GB)

Regression statistics		Values		
R-squared		0.130		
F-statistic		5.975		
Prob(F-statistic)		0.019		
Jarque-Bera		1.792		
Jarque-Bera Probability		0.408		
VIF		1.149		
Prob. Chi-Square (Heteroskedasticity Test)		0.962		
Prob. Cross-section random		0.983		
Observations		42		

Variables	Coefficient	Std. Error	t-Statistic	Prob.
C	79.158	0.667	118.589	0
GB	0.335	0.139	2.414	0.0205

Source: author's processing

The results presented in Table 8, Prob(F-Statistic) = 0.019 (<0.05), VIF<10, Prob. Chi-Square>0.05, Prob. Jarque-Bera Test>0.05, indicate that the regression model is valid and green bonds have a statistically significant influence on the Sustainable Development Index. The link between indicators is direct (0.335), 13% of the change in the dependent variable (SDG) is explained by the change in the independent variable ($R^2=0.13$). By increasing the value of green bonds amount issued as a percentage of GDP by one unit, the Sustainable Development Index can be increased from 79.23 points to 79.49 points (by 0.33%).

The results achieved in Tables 1 to 8 allow us to note that, in CEE countries, green bonds have a positive impact on digital performance indicators, innovation indicators, human capacity development and sustainable

human capacity development, and support sustainable development.

The information and results obtained in this research are the first of its kind to highlight the influence of sustainable finance on the implementation of technologies and competencies of Industry 4.0. Both nationally and internationally, no such approach has been identified. Even if in the CEE countries sustainable finance is at an early stage of development, the results obtained are promising and urges us to pay more attention to this type of financing in achieving the objectives of Industry 4.0.

Future research perspectives may include identifying other sources of funding, relevant to achieving the expectations of Industry 4.0, and why not, of Industry 5.0.

6. REFERENCES

- [1] International Federation of Robotics, World Robotics 2021 Industrial Robots.
- [2] OECD Science, Technology and Industry Scoreboard 2017, <https://doi.org/10.1787/9789264268821-en>.
- [3] European Commission, Research and Innovation, Policy Brief: Industry 4.0, 2019.
- [4] Aoun, A., Ilinca, A., Ghandour, M., Ibrahim, H., *A review of Industry 4.0 characteristics and challenges, with potential improvements using blockchain technology*, Computers & Industrial Engineering, 2021, 162: 107746.
- [5] Covaciu F., *Designing and manufacturing a Delta Robot for pick and place applications*, Acta Technica Napocensis - Series: Applied Mathematics, Mechanics, and Engineering, 2020, 63(1).
- [6] Covaciu, F., *Control and actuation system of a six degrees of freedom robotic arm*, Acta Technica Napocensis - Series: Applied Mathematics, Mechanics, and Engineering, 2019, 62(1).
- [7] Covaciu, F., *Actuation and control of a serial robotic arm with four degrees of freedom*, Acta Technica Napocensis - Series: Applied Mathematics, Mechanics, and Engineering, 2018, 61(3).
- [8] Covaciu, F., Covaciu L.N., *Control and actuation a parallel robot with three degrees of freedom*, Acta Technica Napocensis - Series: Applied Mathematics, Mechanics, and Engineering, 2022, 65(1).
- [9] Beier, G., Niehoff, S., Ziems, T., Xue, B., *Sustainability aspects of a digitalized industry – A comparative study from China and Germany*, International Journal of Precision Engineering and Manufacturing-Green Technology, 4(2), 2017, pp. 227-234.
- [10] Müller, J.M., Voigt, KI, *Sustainable Industrial Value Creation in SMEs: A Comparison between Industry 4.0 and Made in China 2025*, International Journal of Precision Engineering and Manufacturing-Green Technology, 5(5), 2018, pp.659-670.
- [11] Beltrami, M., Orzes, G., Sarkis, J., Sartor, M., *Industry 4.0 and sustainability: Towards conceptualization and theory*, Journal of Cleaner Production, 2021, 127733.
- [12] Khan, I. S., Ahmad, M. O., Majava, J., *Industry 4.0 and sustainable development: A systematic mapping of triple bottom line, Circular Economy and Sustainable Business Models perspectives*, Journal of Cleaner Production, 2021, 126655.
- [13] Yu, Y., Zhang, J. Z., Cao, Y., Kazancoglu, Y., *Intelligent transformation of the manufacturing industry for Industry 4.0: Seizing financial benefits from supply chain relationship capital through enterprise green management*, Technological Forecasting and Social Change, 2021, 172: 120999.
- [14] Barata, J., *The fourth industrial revolution of supply chains: A tertiary study*, Journal of Engineering and Technology Management, 2021, 60: 101624.
- [15] Daú, G., Scavarda, A., Scavarda, L. F., Portugal, V. J. T., *The healthcare sustainable supply chain 4.0: The circular economy transition conceptual framework with the corporate social responsibility mirror*, Sustainability, 11(12), 2019, 3259.
- [16] de Assis Dornelles, J., Ayala, N. F., Frank, A. G., *Smart Working in Industry 4.0: How digital technologies enhance manufacturing workers' activities*, Computers & Industrial Engineering, 2021, 107804.
- [17] Ghadimi, P., Donnelly, O., Sar, K., Wang, C., Azadnia, A. H., *The successful implementation of industry 4.0 in*

- manufacturing: An analysis and prioritization of risks in Irish industry*, Technological Forecasting and Social Change, 2022, 175: 121394.
- [18] Grenčíková, A., Kordoš, M., Bartek, J., Berkovič, V., *The Impact of the Industry 4.0 Concept on Slovak Business Sustainability within the Issue of the Pandemic Outbreak*, Sustainability, 13(9) 2021, 4975.
- [19] Müller, J. M., Buliga, O., Voigt, K. I., *The role of absorptive capacity and innovation strategy in the design of industry 4.0 business Models-A comparison between SMEs and large enterprises*, European Management Journal, 39(3), 2020, pp.333-343.
- [20] Deopale, C. C., Ghiculescu, L. D., Cristea, B. I., *Industry 4.0 in Romania – A practical analysis of the country potential from economic and human resources perspective to support a sustainable development of cement smart factories*, Acta Technica Napocensis - Series: Applied Mathematics, Mechanics, and Engineering, 2021, 64(4s).
- [21] Yuan, S., Musibau, H. O., Genç, S. Y., Shaheen, R., Ameen, A., Tan, Z., *Digitalization of economy is the key factor behind fourth industrial revolution: How G7 countries are overcoming with the financing issues?*, Technological Forecasting and Social Change, 2021, 165: 120533.
- [22] European Commission, *Strategy for financing the transition to a sustainable economy*, Strasbourg, 2021.
- [23] Climate Bonds Initiative, *Sustainable Debt, Global State of the Market 2021*.
- [24] European Commission, *European Innovation Scoreboard 2021*, Brussels, 2021.
- [25] European Commission, *Digital Economy and Society Index (DESI) 2021*, Brussels, 2021.
- [26] Human Development Report 2020, By the United Nations Development Programme, 1 UN Plaza, New York, NY 10017 USA, ISSN: 0969-4501.
- [27] Sachs, J., Kroll, C., Lafortune, G., Fuller, G., Woelm, F., *The Decade of Action for the Sustainable Development Goals: Sustainable Development Report 2021*. Cambridge: Cambridge University Press, 2021.

ÎNDEPLINIREA OBIECTIVELOR INDUSTRIEI 4.0 SUB INFLUENȚA FINANȚĂRII SUSTENABILE

Rezumat: Utilizând datele oficiale ale UE pentru 7 țări din zona Europei Centrale și de Est (CEE), în cadrul acestui studiu a fost analizat impactul finanțelor sustenabile asupra îndeplinirii obiectivelor Industriei 4.0. Rezultatele obținute ne permit să afirmăm că, finanțele sustenabile (reprezentate de finanțele verzi) au potențial de a contribui la îmbunătățirea indicatorilor ce reflectă tranziția către Industria 4.0 în țările din CEE. Astfel, finanțarea sustenabilă are potențial de a sprijini performanța digitală, poate promova inovațiile, are potențial de a contribui la dezvoltarea capacității umane, și poate sprijini dezvoltarea durabilă. În țările CEE finanțele sustenabile reprezintă o pondere încă redusă în mixul surselor de finanțare disponibile dar rezultatele obținute relevă faptul că sunt șanse mari ca finanțele sustenabile să aibă în perioada următoare un rol mult mai însemnat în sprijinirea proiectelor inovatoare ale Industriei 4.0.

Laura-Nicoleta COVACIU, Ph.D. Student, Technical University of Cluj-Napoca, Faculty of Industrial Engineering, Robotics and Production Management, Department of Management and Economic Engineering, laura.covaciu@gmail.com, Phone: 0724564015, Bulevardul Muncii street, no. 103-105, Cluj-Napoca, ROMANIA.

Florin COVACIU, PhD. Eng., Associate professor, Technical University of Cluj-Napoca, Faculty of Industrial Engineering, Robotics and Production Management, Department of Design Engineering and Robotics, Florin.Covaciu@muri.utcluj.ro, Phone: 0755566491, Bulevardul Muncii street, no. 103-105, Cluj-Napoca, ROMANIA.

Laura BACALI, Professor, Technical University of Cluj-Napoca, Faculty of Industrial Engineering, Robotics and Production Management, Department of Management and Economic Engineering, laura.bacali@mis.utcluj.ro, Phone: 0264401782, Bulevardul Muncii street, no. 103-105, Cluj-Napoca, ROMANIA.