SHS Web of Conferences **176**, 02002 (2023) https://doi.org/10.1051/shsconf/202317602002
BRD2023

Industry 5.0, Digitalization of business and Circular economy

Nikolay Sterev[1]*

[1]UNWE, Business Faculty, 19 8-mi Decemvri str. Sofia, Bulgaria

Abstract. As we are on the road to the next generation of the business organizations: Industry 5.0, we need to understand how the digitalization is connected to the requirements of the circular economy. Although we could find a statistical evidence for such strong relations, the digitalization is much more requisition for the business success as the circular economy is a business intention. Thus, there is not significant reason-react dependence between these two business processes. And the paper aims to find out the exact dependence between them. Thus, the paper not just present the main foundations of the digitalization and circularity of economics (in 1st paragraph) but develop a research instrument (in 2nd paragraph) for analysis the exact correlation between ""industrial policy"" - ""Industry 5.0 digital instruments development"" - Policy for Circular Economy development. The main results are focused on the preferred policy instruments that force up the development of circular economy based on the business intention to digitalization and Industry 5.0 application.

1 Introduction

The general reports on the sustainable development and green economy impact show that the World become worse and worse place to live besides the overall policy is to reduce it. Just for example, the WEF [1] calculates the earth overshot days and it determinates that we need 1.75 Earths to continue living on the same way. Additionally, the most developed countries need more than 3.0 Earths (e.g. USA – 5.1; Germany – 3.0; Japan – 2.9 and etc.) as the BRICS countries need less (e.g. China – 2.4; Brazil – 1.6; India – 0.8 and etc.). Despite the Green Deal policies, the higher technology developed countries looks like less climate change oriented one (e.g. the EU has to become energy neutral since 2050 but it needs much more resources to do that).

Accordingly, the main question is how digitalization and Industry 5.0 future will react to the circularity of the economy and its main indices. As the numerous of papers discuss, there is a strong linkage as the digitalization leads to more circularity based on better resource efficiency, better energy efficiency and further CO_2 footprint reduction. But, where are the limits of this interrelation?

* Corresponding author: sterew@abv.bg

1.1 “Circular economy” future

Undoubtedly, ¨circular economy¨ (CE) become a ¨new normality¨ in business. As the concept has been promoted firstly by Kenneth Boulding [2] and then developed recently by Ellen MacArthur Foundation [3-4] and a Circular economy action plan as a part of EU Green deal strategy [5].

Following the already accepted definitions, the circular economy is explained as a production system for generation and utilization of existing resources that could be based on sharing assets, repairing and reusing. In this way products and materials are delivered with expanding lifecycle. Accordingly, two definitions have to be given [6]:

- “A circular economy describes an economic system that is based on business models which replace the **‘end-of-life’ concept** with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes” [7];
- “[CE] an industrial system that is restorative or regenerative by **intention** and design” [3, 8]

1. CE is a business model, a concept of business processes’ organization, that implies a different approach to the materials/resource usage. Accordingly, the CE is based on the same business approach as the “rejected” Linear economy (LE) model is. Looking the business economics basics [9] the main reason to exist certain business is profit and financial sustainability as Devenport, Taylor, Fayol and others have been stated for the basics of contemporary business organization [10-12]. Thus, we could mark a great risk for the future of CE as it has to be profitable in order to exist.
2. The CE end-of-life approach explain the business intention. Thus, the CE model will be accepted and implemented if the business (resp. business organizations, and mostly their management) receive much more benefits from it than the LE model. As following the behavioral theory, the companies have to do something if it beneficiary for them. Additionally, most of the business behavioral theories focus on the societal element of the behavior [13] and more precisely – on the concept of “followers”. Thus, business intention will become into-action if expectance of the other businesses to have intention to become into-action (resp. it’s is similar to innovation acceptance model; on-topic research publication and etc.)

So, the business behavior basics rise some suspicious about the opportunities by targeted policy to reduce decoupling between human (resp. business) impact on the ecological systems and business intention to (profitable) growth (Fig.1)

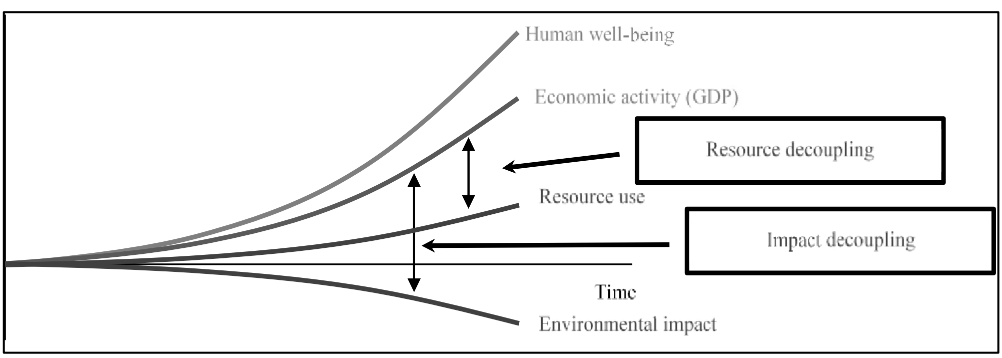

Fig. 1 Long term sustainability of production and consumption patterns
Source: [14-15]

The given constrains are found by Heshmati [16] based on [17-18] that summarized slow policy effect on CE instruments because of higher costs and less benefits for business accepting CE principles, incl. new hi-tech technology innovations. Some reasonable effects could be found by analysing European practices:

- Firstly, as the Circular economy action plan [5] stated, the circularity of the business will be based into-action activities for: assessing options for further promoting circularity in industrial processes; supporting the sustainable and circular bio-based sector; promoting the use of digital technologies for tracking, tracing and mapping of resources; promoting the uptake of green technologies; and **fostering circular industrial collaboration among SMEs**.
- But, secondly, the European Innovation Council (EIC) through Business Acceleration Services supports innovative projects and companies getting access to market, and some of the major questions are about: entrepreneurial success; opportunity for venture capitals; and go-2-market opportunities. And, nothing about: resource effectiveness; reuse or re-think, as main pillars of the CE (the last activities to –action the CE intention, see above point). According to [19] the CE incentives are used to encourage business actors to intent or to act as the societal change needs engagement and education incentives. Additionally, [20] discovered that there is inability of contemporary business to implement a CE' principles using an **entrepreneurial model** where resources and profit are the primary considerations

Nevertheless, the CE is based on some business actions, known as **Rs**. The core CE concept includes **3R**: reduce, reuse, recycle; **6R**: 3R+ recover, redesign, remanufacture; and **9R**: 6R+ refuse, rethink, repurpose. Following latest innovation intents, the Industry 4.0/5.0 technologies integrating different digital resources to helping business to reduce waste and to increase resource efficiency by decoupling with regional resource inequalities. Additionally, newest (digital) technologies help business for adopting green practices as reducing process' consumption of natural resources such as water and energy [21]. Understanding the R's concept is set in the core of digital transformation as Industry 4.0 / Industry 5.0 directly impact over business processes that focus on the main pillars of CE.

1.2 Business digitalization

The new technologies are undisputable element of the CE as they are appointed directly in the EC Action plan to CE [5]. As [22] noticed, the linkage between physical material flows with digital flows is more useful than the recycling way of CE. Additionally, the Industry 4.0/Industry 5.0 instruments give the opportunities for real materials flow optimization. Thus, growing digital "business-2-business" or "business-2-customers-2-business" interconnections could be allowing faster data transfer on materials flow at negligible marginal costs. Furthermore, digitalization facilitates CE networking and allows them to share materials flows for decoupling regional raw-materials' inequalities [23]

The main instruments that give the CE-digitalization interconnection are summarized by [24] (Table 1.)

Table 1. Impact of digital tools in the circular economy

Instruments	Contribution to the circular economy
Big data	• permits processing and interpreting large volumes of process or/and customers' data • enables materials and assets sharing
Internet of things /IoT/	• connects different devices that gather and exchange data performing efficient business processes, incl. automated manufacturing or smart waste management. • Establishes and extends existing networks and CE supply chains • Increases "B2B" and "B2C" communication that allows optimizing production and physical warehouses' processes

Instruments	Contribution to the circular economy
Artificial intelligence /AI/	• reduces materials waste as allows machines to perform human-like routine cognitive working functions
Block-chains	• facilitates transactions and interactions within the raw-materials' supply chain through decentralised and immutable data exchange • allows establishment a CE-networks
Cloud computing	• offers services of computing resources sharing over the Internet
Online platforms /applications	• enables innovative forms of sharing data for smart management of production, consumption, collaboration and assets sharing between businesses or clients
Machine learning	• prepares materials' flows forecasts with a high degree of accuracy as reduces the human bias in testing and prototyping on new products
Computer Vision	• allows autonomous visual comprehension based on images or sequence of images

The overall effect of digital technologies to CE is found by researchers [21, 25 – 29] They prove the strong relations in the next:

- Industry 4.0 has an impact on CE through minimizing industrial waste, promoting remanufacturing, and making optimal use of natural resources. The recycling strategy benefits from most of such digitalization;
- Environmental, economic, and operational success are made possible by CE practices. In particular, prolonging product lifespans depends on data analysis to match product supply with needs. IoT can help achieve this goal by gathering and disseminating data among users, technicians, service providers, and potential used-car purchasers.
- Business leaders assume responsibility for societal, environmental, and financial benefits by implementing CE practices. The most often used digital functions that have a direct influence on increased process efficiency and decreased material and energy waste are digitalization of monitoring, optimization, and auto-controlling production processes.
- Industry 4.0 increases the level of cooperation and coordination between different stakeholders as utilizing sustainable development may help businesses build solid relationships with their clients and the communities, acquire a competitive edge, and establish fresh revenue sources.
- In order to achieve sustainable economic and social growth, Industry 4.0's new technologies and innovations have supported knowledge- and information-based business models: digital tweens. Based on them, these business models force producers to increase their attention to potential environmental effects, to improve the quality of their product designs, and to consider how they may contribute to sustainable development by giving them a digital perspective of real life as: virtual prototyping; virtual reality or augmented reality assembly and disassembly manufacturing and etc.
- One of the main constrains of is that undoubtedly Industry 4.0 directly impact CE adoption in manufacturing beside Industrial companies with the latest information systems at their disposal, innovative technologies in the production process, intelligent processing of data and etc.

In summary, there are found different interrelations between digitalization and CE application in different sectors and countries. Nevertheless, the linkage between them is based on the introduction of "artificial production systems" that more focused on business profitability by "changing the game" competition with stakeholders and their networks. Hence, digital technologies speed up B2B and B2C communication out of the humans constrains that basically increase resource efficiency and reduce waste.

2 Research methodology and results

Following [15, 30] there are several methodologies and Key Project Indicators systems to measure the effect of CE. Accordingly, the most common used are KPI's of: UNEP, UNDP, EC /Eurostat/ and EMAF.

As we have accepted the EC definition for CE, the main elements of EC KPI set for CE /and the database is available mainly for the EU member states/ are listed next (Table 2):

Table 2. CE KPI set of Eurostat

Indicator set	Characteristic	KPIs
Production and consumption	**Material consumption** Material footprint *tonnes per capita* Resource productivity *index 2000 = 100* **Waste generation** Total waste generation per capita *kg per capita* Generation of waste excluding major mineral wastes per GDP unit *kg per thousand euro, chain linked volumes (2010)* Generation of municipal waste per capita *kg per capita* Food waste *kg per capita* Generation of packaging waste per capita *kg per capita* Generation of plastic packaging waste per capita *kg per capita*	2 sub-groups, 8 KPI
Waste management	**Overall recycling rates** Recycling rate of municipal waste *percentage* Recycling rate of all waste excluding major mineral waste *percentage* **Recycling rates for specific waste streams** Recycling rate of overall packaging *percentage* Recycling rate of plastic packaging *percentage* Recycling rate of WEEE separately collected *percentage*	2 sub-groups, 5 KPI
Secondary raw materials	**Contribution of recycled materials to raw materials demand** Circular material use rate *percentage* End-of-live recycling input rates (EOL-RIR), aluminium *percentage* **Trade in recyclable raw materials** Imports from non-EU countries *thousand tonnes* Exports to non-EU countries *thousand tonnes* Intra EU trade *thousand tonnes*	2 sub-groups, 5 KPI
Competitiveness and innovation	Private Investments *percentage of gross domestic product (GDP) at current prices* Persons employed *percentage of total employment* Gross value added *percentage of gross domestic product (GDP) at current prices* **Innovation** Patents related to waste management and recycling *number*	2 sub-groups, 4 KPI
Global sustainability resilience	**Global sustainability from circular economy** Consumption footprint *Index 2010=100* GHG emissions from production activities *kg per capita* **Resilience from circular economy** Material import dependency *percentage* EU self-sufficiency for raw materials, aluminium *percentage*	2 sub-groups, 4 KPI

Source: [31]

Focusing on the core CE concept: 3R and following [30, 32-34] in adopting circular economy approaches, we test the effects on CE based on: **R**ecover – **R**ecycle – **R**euse model.

- **Production and consumption** KPI / **R**ecover/: The CE waste and eco-efficiency (code: cei_pc031): The indicator measures the waste collected by or on behalf of municipal authorities and disposed of through the waste management system. It consists to a large extent of waste generated by households, though similar wastes from sources such as commerce, offices and public institutions may be included.

- **Waste management** KPI / **R**ecycle:/ The CE Recycle index (code: cei_wm011): The indicator measures the share of recycled municipal waste in the total municipal waste generation. Recycling includes material recycling, composting and anaerobic digestion. The ratio is expressed in percent (%) as both terms are measured in the same unit, namely tonnes.
- **Secondary raw material** KPI /**R**euse/: The CE recyclable waste trade (code: cei_srm020): measures the quantities of selected waste categories and by-products that are shipped between the EU Members States (intra-EU) and across the EU borders (extra-EU). The indicator includes the following variables:

o Intra EU trade of recyclable raw materials (measured as the Imports from EU countries)
o Imports from non-EU countries and exports to non-EU countries of recyclable raw materials (as regards extra-EU trade).

Testing the CE-digitalization relation is based on the Bulgarian national projects for Technological Development and Innovation Program as for the period 2014 – 2020 are applied 415 national projects for 164.8 mln. euro.

Following [24] 2models of dependency are construct: model before digital projects and model with digital projects (Fig.2.)

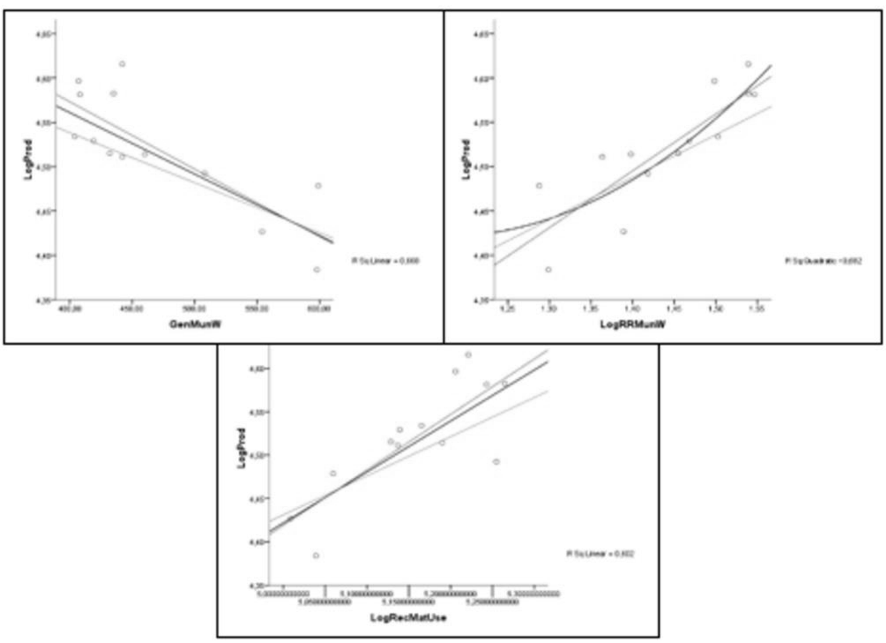

Fig. 2. Linear regression relationship between Change in output (Prod) and change in waste collection (GenMuW), recycling rate (RRMunW) and trade in recycled materials (RecMatUse)
Source: Eurostat and own calculations based on methodology in [24, 34]

The specific differences are observed in the following Table 3.

Table 3 Coefficients of (linear) dependence between CE variables

		Coefficients 2008-2020					Coefficients 2008-2013					Change in B, %
Model		Unstandard. Coeff.		Standard. Coeff.	t	Sig.	Unstandard. Coeff.		Standard. Coeff.	t	Sig.	
		B	Std. Error	Beta			B	Std. Error	Beta			
1	LogMatFoot	0,851	0,262	0,700	3,247	0,008	0,371	0,434	0,308	0,856	0,421	129%

2	LogGenMunW	-0,867	0,187	-0,814	-4,640	0,001	-0,648	0,150	-0,852	-4,311	0,004	34%
3	LogWGen	-0,590	0,276	-0,691	-2,140	0,085	-0,292	0,346	-0,437	-0,842	0,461	102%
4	LogRRMunW	0,640	0,120	0,849	5,336	0,000	0,478	0,189	0,691	2,532	0,039	34%
5	LogRecMatUse	0,639	0,143	0,803	4,463	0,001	0,450	0,177	0,693	2,541	0,039	42%

Source: [31]

The data (Figure 2 and Table 3) confirm the Hypothesis that introduction of resource efficient digital technologies increases the impact of generated waste on manufactured products by 34%. The same relative share (34%) is observed to have a positive impact on the extent of waste recycling for increased production. All of this had a positive effect, with a 42% increase in trade in recycled materials and an increase in production.

3 Conclusions and next steps

As we confirm the positive impact of Industry 4.0/5.0 and digitalization to the CE, the effects are not significant enough. The main reasons are set as constrains in defining the Circular economy. Thus, there are 3 types of policy instruments that could be performed.

3.1 Smart Circular economy

Accepting the state of [26] there is a knowledge gap on the precise internal resources and competencies needed to utilize data and analytics that have an influence on a company's performance and methods based in established management. Thus, they found a need of Smart CE (Fig 3.).

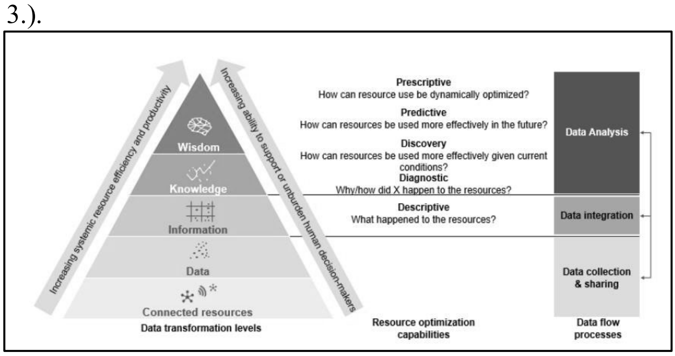

Fig. 3 Smart circular economy framework
Source: [35]

So, business to-action intention become bigger if the governmental policy instruments cover not just data flow processes but smart data analysis as well. Additionally, most of the financed digital projects in Bulgaria cover just data flow and data collection: and this could be explanation for the slow CE growth. The shift from LE to CE will become faster if the project includes data analysis elements.

3.2 Circular economy training

Accepting [13] and revising the entrepreneurial characteristics [36-37], there is need to set field of circular entrepreneurial competencies [38]:

- Ideas and opportunities: CE concept should be a part of entrepreneurial understanding. Thus, the smart CE entrepreneurs should have competencies for:
  - Rethinking: orientation to sharing assets that makes products more intensive in use.

- Coping with waste (Refuse): orientation to refuse project ideas that generate waste.

- Resources: CE concept should be placed as intention to resources:

- Reuse: entrepreneurial ideation is based on second used products that are discarded from another business.
- Repurpose: mobilising entrepreneurial resources to change the original usage of discarded products.

- Into-action: Cooperation and networking intention: express willingness for co-working and co-creation with other stakeholders.

3.3 Circular economy Training

And, at last but not least, encouraging circular economy policy making using digital technologies and the data they generate. Besides playing a crucial role in circular business models, digital innovation and the uptake of digital solutions may also help improving circular economy policy making. In order to transpose this link into practice, governments should consider exploring data-driven approaches to their foresight capacities in order to better anticipate environmental and societal trends and needs, and as such to increase efficiencies and better target circular economy policy making.

For example, establishment appropriate CE framework shall be based on adding a huge expansion in data transfer and data analysis, incl.:

- Proposing a stress tests for companies/projects funded by the EU Cohesion Fund under National Recovery and Sustainability Plans and as a prerequisite for participating in project competition.
- Introduce CE target criteria for project financing and improve pre- and post-project stress test values.
- Development a national Plan for CE training campaign for SMEs focused on establishing engagements to the transition to a circular economy.
- Introducing a digital platform / national registry of companies related to the circular economy/and their best practices/.

In conclusion, the shift from LE to CE is not doubtful with support of new Industry 4.0/5.0 digital technologies. But, impact of digitalization to CE will be greater and faster if there is intention-oriented support as: training to CE competencies; public register for best CE practices /to do in-action the followers of SMEs/ and etc.

The publication contains the results of a study financed with funds from a targeted subsidy for the UNWE Research Fund under contract No. NID NI 4/2022/A “Entry of Bulgarian enterprises into the knowledge economy – modern aspects and challenges”.

References

1. World Economic Forum, Earth Overshoot Day. What is it and why do we need it? (2022), [Online] Earth Overshoot Day: Human consumption vs biocapacity | World Economic Forum (weforum.org)
2. K. E. Boulding, *The Economics of the Coming Spaceship Earth*, in Jarrett, H. (ed) Environmental quality in a growing economy: Essays from the sixth RFF forum, (New York, RFF Press, 3–14, 1966)
3. Ellen MacArthur Foundation, Towards the circular economy: Economic business rationale for an accelerated transition (EMAF, London UK, 2013)
4. Ellen MacArthur Foundation, Towards a circular economy: Business rationale for an accelerated transition, (2015), [Online]

https://www.ellenmacarthurfoundation.org/assets/downloads/TCE_Ellen-MacArthur-Foundation_9-Dec-2015.pdf

5. EC (2020) A new Circular Economy Action Plan: For a cleaner and more competitive Europe, COM(2020) 98 final, Brussels, (2020), [Online] EUR-Lex - 52020DC0098 - EN - EUR-Lex (europa.eu)
6. N. Sterev, TJS **17**, 1, 511-523 (2019)
7. J. Kirchherr, D. Reike, M. Hekkert, Resour., Conserv. Recycl. **127**, 221–232 (2017)
8. M. Geissdoerfer, et al., J. Clean. Prod. **143**, 757–768 (2017)
9. N. Sterev, P. Penchev, *Historical Development of Business Economics: Bulgarian Case*, in Çalıyurt K.T. (ed.), History of Accounting, Management, Business & Economics **I**, Elsevier, (2023)
10. H. Devenport Economics of Enterprise (1924)
11. R. W. Taylor, Principles of Scientific Management (1911)
12. H. Fayol, Administration industrielle et generale (1925)
13. K. Glykeria, Y. Caloghirou, *Production technologies and innovation in knowledge-intensive low-tech ventures: evidence from the Greek wood and furniture industry*, in Proceedengs of 6th Annual EuroMed Conference of the EuroMed Academy of Business: Confronting Contemporary Business Challenges through Management Innovation, 23-24 September 2013, Estoril, Cascais, Portugal (2013)
14. UNEP, 201. Decoupling natural resource use and environmental impacts from economic growth: a report of the Working Group on Decoupling to the International Resource Panel. Paris. [Online] http://www.unep.org/resourcepanel/decoupling/files/pdf/decoupling_report_ english.pdf [Accessed: 3 September 2019]
15. EASAC, Indicators for a circular economy, EASAC policy report 30, (2016), [Online] https://www.easac.eu/fileadmin/PDF_s/reports_statements/Circular_Economy/EASAC_Indicators_web_complete.pdf [Accessed: 3 September 2019]
16. A. Heshmati, A Review of the Circular Economy and its Implementation, Discussion Paper No. 9611, Sogang University and IZA (2015)
17. H. Shi, S.Z. Peng, Y. Liu, P. Zhong, J. Clean. Prod. **16**, 7, 842-852 (2008)
18. X. Xing, Y.D. Wang, J.Z. Wang, The problems and strategies of the low carbon economy development, Energy Procedia **5**, 1831-1836 (2011)
19. M. Geißdörfer, P. Savaget, N. Bocken., E-J. Hultink, J. Clean. Prod. **143**, 757-768 (2017)
20. A. Genovese, M. Pansera, Capitalism Nature Socialism **32**, 2, 95-113 (2021)
21. S.A.R Khan, M. Umar, A. Asadov, M. Tanveer, Z. Yu, Sustainability **14**, 4524 (2022)
22. S. Ramesohl, H. Berg, J. Wirtz, *The Circular Economy and Digitalisation – Strategies for a digital-ecological industrial transformation*, study within the project “Shaping the Digital Transformation”, Wuppertal (2022)
23. E. Barteková, P, Börkey, *Digitalisation for the transition to a resource efficient and circular economy*, OECD Environment Working Papers, No. 192, OECD Publishing, Paris, (2022), [Online] https://doi.org/10.1787/6f6d18e7-en.
24. N. Sterev, P. Biolcheva, *Intelligent systems in the circular economy*, in Proceedings of the VIth International Conference on Management and Strategic Decisions (ICGSM), 8-10 June 2023, Bourgas, Bulgaria (to be published)

25. Q. Liu, A. H. Trevisan, M. Yang, J. Mascarenhas, Business Strategy and the Environment **31**, 5, 1–22 (2022)
26. W. Naveed, M. Ammouriova, N. Naveed, A. A. Juan, Sustainability **14**, 15587 (2022)
27. R. Y. Zhong, X. Xu, E. Klotz, S.T. Newman, Engineering **3**, 616–630 (2017)
28. Y. Han, T. Shevchenko, B. Yannou, M. Ranjbari, Z. Shams Esfandabadi, M. Saidani, G. Bouillass, K. Bliumska-Danko, G. Li, Sustainability **15**, 2067 (2023)
29. S.A.R Khan, P. Ponce, G. Thomas, Z. Yu, M.S. Al-Ahmadi, M. Tanveer, Sustainability **13**, 12790 (2021)
30. N. Sterev, V. Ivanova, *Circular Economy: New Opportunities for Growth*, in: M. H. Bilgin, H. Danis, E. Demir, S. Vale, (eds) Eurasian Economic Perspectives. Eurasian Studies in Business and Economics **16**/1. Springer, Cham. (2021)
31. Eurostat, Monitoring framework - Circular economy - Eurostat (europa.eu)
32. V. Ivanova Circular Economy in Bulgaria – Perspectives and Challenges, Nauchni trudove **5**, UNWE, Sofia, Bulgaria, 203-215 (2019)
33. V. Ivanova, Journal of Innovative Business and Management **12**, 1, 9-17 (2020)
34. N. Sterew, V. Ivanova, *From sustainability to a model of circu8lar economy - the example of Bulgaria*, in Proceedings of INTCESS 2019- 6th International Conference on Education and Social Sciences, 4-6 February 2019- Dubai, U.A.E., 757-766 (2019)
35. E. Kristoffersen, F. Blomsma, P. Mikalef, J. Li, Journal of Business Research **120**, 241–261 (2020)
36. D. Yordanov, Entrepreneurship **VII**, 1, 7-15 (2019)
37. D. Yordanov, Toolkit for Assessing Entrepreneurial Competencies among learners, Strategii na Obrazovatelnata i Nauchnata Politika – strategies for policy in science and education, Number **3**s /2023, 25-44 (2023)
38. N. Sterev, Pre-Incubation Toolkits for Academic Entrepreneurship Fostering: Bulgarian Case, Strategii na Obrazovatelnata i Nauchnata Politika – strategies for policy in science and education, Number **3**s /2023, 90-103 (2023)