Digitalization intensity of the Romanian bioeconomy

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***Abstract**: The technological transformation has recently reached new heights and has challenged all industrial sectors to adapt in different ways. Our research focuses on determining the intensity of digitalization of the Romanian bioeconomy, as the main branch of the economy and intensely promoted due to its linkage to sustainable development. The indicators considered to determine the degree of intensity of the digital transformation reflect three key components in streamlining the way an organization works: equipment, resource planning, and data management. The results have highlighted the importance and the need for urgent investments in most sectors for better resource planning and efficient data processes.*

***Keywords**: digitalization, bioeconomy, agriculture, taxonomy;*

***JEL Classification**: O11, O13, Q16, Q22, Q23, Q25*

Introduction

The speed of technological development has reached new heights, forcing all industries to adapt and implement new strategies and business models to survive. This phenomenon has not only grown in speed but also in complexity, turning the businesses as well as their economic sectors into warriors across multiple fronts to face its multifaceted transformation (Calvino et al., 2018). All these enchained events have materialized into completely new digital outputs as well as enhanced existing products and models (Paunov & Planes-Satorra, 2019). A new concept has been defined and has been assigned to a so-called fourth industrial revolution, namely 4.0 industry. It was created to capture the latest innovations in process automation and human-machines communications (Klitkou et al., 2017). In terms of

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drivers, the same author highlights a socio-economic layer characterized by shorter development periods, flexible process methodologies and highly customizable products, all of these created in an efficient and environmentally friendly way. The second driver would be represented by the high demand for digital solutions that can automate most of the repetitive human work. Henceforth, several essential technologies were adopted in all the industries to secure their long-term existence: digital equipment for the employees, software investments, databases and cloud solutions, robots, engagement on the internet, e-commerce and online payments (Calvino et al., 2018). These can be supported by innovative digital solutions such as the internet of things, big data analytics, and artificial intelligence. The effects of the new industry have been propagated through all the sectors, including the ones with deep tradition in a country's economy, such as agriculture, but it has created new ones as well.

At the same time, the need to transform economic processes to ensure a sustainable way of life has led decision-makers to act by implementing public policies and opening new research opportunities. In this category, we include the concept of bioeconomy, influenced by the implications of the circular economy. The global importance of this area is determined primarily by its contribution to all pillars set out in the European Union's sustainable development policies, including the European Green Deal (European Commission, 2019): biodiversity, the food sector, green energy, infrastructure, competitive industry and waste management. On a lower scale, this sector encompasses parts of the biggest industrial contributors to the Romanian gross domestic product, namely agriculture, forestry and fisheries, manufacturing, as well as service sectors, as stated by Tatomir & Popovici (2011), World Bank (2020).

The present study will focus on presenting the technological development of one of the most dynamic branches of the economy, the bioeconomy (Golembiewski et al., 2015), which encompasses traditional sectors, but also innovative ones. Our approach comes in addition to the available evidence from Calvino et al. (2018) and brings an actual overview of the Romanian market in comparison to the European counterparts. Even though the existing studies are showing a comprehensive view of the global digitalization of all the business sectors, the results might have become outdated due to the fast development of the new technologies and transformation of the sectors. In consequence, the main research scope will be to determine the digitalization intensity of the main bioeconomy sectors in Romania, starting with a trend analysis throughout the years and comparisons with the same sectors at the European level. Nevertheless, on a secondary plan, the questions that will arise would be whether the digitalization intensity is enough for the agricultural sector to recover the advance lost in recent years to maintain its place on the podium for the contribution to the country's GDP, or for the manufacturing sector to push even further the theoretical limits of economic growth.

Literature review

An important role in our research is played by the rapid digital development of the bioeconomy and its transformative model that incorporates several digital solutions and engages all relevant stakeholders. From this statement, we derive the two key concepts to be approached for a better understanding of the situation in Romania: bioeconomy and digitalization.

The reference point of the concept of bioeconomy lies in its very definition, developed by the European Commission. It is considered the part of the economy that relies on the transformation of renewable biological resources into finished products for several sectors, including primary ones (agriculture, forestry, fisheries). Although the bioeconomy may include all sectors that rely on biological resources (European Commission, 2018), most studies use and recommend sectors directly linked to the system of national accounts for consistency, comparability, and the ease of retrieving statistical data (Efken et al., 2016; Biomonitor, 2019; Bracco et al., 2019).

Despite its implications into traditional economic domains, the bioeconomy is still considered a branch under full development (Bröring et al., 2020). As of November 2019, Romania did not have its bioeconomy strategy, but it was part of an initiative of the Central and Eastern countries (Robert et al., 2020). The Knowledge Center of the European Commission (2019) has highlighted a turnover of more than 24 million Euro from the bioeconomy sectors, placing Romania in the 18th position in Europe. The numbers would have been higher if the agriculture data had been included, as this sector represents the focus of the national policies (Butu et al., 2020). The number of people employed in one of the sectors of bioeconomy is almost the highest in the European Union, placing Romania in second place, right after Poland. However, when adding digitalization to the equation, we will observe a lower performance of the South-Eastern country, mainly due to insignificant investments in the integration of digital technologies and use of the internet, as highlighted by the 2020 Digital Economy and Society Index (European Commission, 2020). That is to say, we aim to address the intensity of digital transformation of the bioeconomy sectors in Romania as of today, compared to previous years, and assess possible solutions to be considered for implementation.

Based on the analysis made by OECD on all economic sectors for its member states (Calvino et al., 2018), we will emphasize the impact of digitalization on the Romanian bioeconomy and its evolution throughout the years. A similar approach was taken by Santos and Lomardo (2019) for all sectors between 2010 and 2014 to highlight the digital intensity of the economy in Portugal. The results have shown low investments in technology for agriculture, mining, and real estate, and very high in broadcasting activities, IT&C and the financial sector. In conclusion, the success factors for an impactful digitalization are represented by a long-term vision, efficient leadership and proper financing.

Several studies on the new business models for a digitalized bioeconomy were published, enabling big data analysis systems, smart design, efficient management and integration of all streams through efficient data management and new solutions (Watanabe & Naveed, 2019). Paunov and Planes-Satorra (2019) stated that each of the economic sectors has different data needs and, implicitly, different business models on digitalization due to the specific dynamics that are impacted by the differences in opportunities. For example, the agricultural sector is more focused on business data such as farm sensors aggregated data (Wolfert et al., 2017) or satellite imagery, while the retail sector is dealing in a significant percentage with customers' personal data. Therefore, the digitalization process develops at different speeds. Another factor worth to be mentioned is the level of saturation that changes the way a sector can be compared to another (Bröring et al., 2020). If we compared agriculture with the pharma sector, we would discover fewer implications of technological development in the first one.

Methodology

Within the current research, a quantitative approach has been chosen to explore the transformative direction of the bioeconomy sectors, based on several drivers in digitalization.

As previously considered by Clavino et al. (2018), the following measures will be used to determine the digital intensity of the bioeconomy in Romania: software and database investment, computing equipment, robots and other machinery. In addition to the ones mentioned above, the following indicators are being introduced, as the statistical data has recently become available: investment in ERP software packages, online payment for web sales, investments in the Internet of Things. The choice of indicators was mainly driven by the availability of comparable data among the European countries, as well as their coverage and topicality. The second factor was determined by the companies' behavior when choosing to invest in digital assets and how they approach the market and customers' needs. Therefore, the path chosen by the enterprises to update their business models was built around tangible assets such as equipment and programs, but also around education and research (Jander et al., 2020). Our data was sourced from Eurostat, EU-KLEMS and OECD Statistical Database for Romania and the European Union. Several bioeconomy sectors were not included in the analysis due to data unavailability. The NACE codes used from each data source are presented in Table 1.

Table 1 - List of sectors included in the analysis, by NACE code

NACE	Source
A01-03 Crop and animal production, hunting and related service activities, forestry and logging, fishing and aquaculture	EU-KLEMS, OECD Statistical Database, not available for the indicators retrieved from Eurostat

NACE	Source
C10-12 Manufacture of food, beverages, tobacco	EU-KLEMS, Eurostat
C13-15 Manufacture of textiles, wearing apparel, leather and related products	EU-KLEMS, Eurostat
C16-18 Manufacture of wood and paper products, printing and reproduction of recorded media	EU-KLEMS, Eurostat
C20 Manufacture of chemicals and chemical products	EU-KLEMS, not available for the indicators retrieved from Eurostat
C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations	EU-KLEMS, not available for the indicators retrieved from Eurostat
D35 Electricity, gas, steam and air conditioning supply	EU-KLEMS, Eurostat
E36-39 Water collection, treatment and supply, sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services	EU-KLEMS, not available for the indicators retrieved from Eurostat

Source: Authors' computation

Where the overall values were not available, they were calculated based on individual countries' available data. For each data set that was initially provided in current prices as a unit of measure, the percentages of the relevant sectors from the non-residential investment were calculated. As a benchmark, every second year was chosen, starting with 2006, the last year before Romania joined the community and the most recent year with available data. This approach will help us compare and discuss the evolution of the country's digital bioeconomy. The following table presents the data sets chosen for our study and the indicator resulting after computation.

Table 2 - List of indicators for digital transformation, grouped by IT&C pillar in an organization

Clusters and indicators	Period	Unit of measure	Code
1. Equipment and substitutes			
1.1 Computing equipment	2006, 2008, 2010, 2012, 2014, 2016	Current prices (% of total)	1.1
1.2 Machinery and equipment (other than computing)	2006, 2008, 2010, 2012, 2014, 2016	Current prices (% of total)	1.2
1.3 Cloud computing services used over the internet	2014, 2016, 2018, 2020	%	1.3
2. Resource planning and security			
2.1 Enterprises that have ERP software package to share information between	2010, 2012, 2014, 2016	%	2.1

Clusters and indicators	Period	Unit of measure	Code
different functional areas			
2.2 Enterprises using software solutions like Customer Relationship Management (CRM)	2008, 2010, 2012, 2014, 2016	%	2.2
2.3 Enterprises using ICT security measures	2010, 2018	%	2.3
3. Data management			
3.1 Computer software and databases	2006, 2008, 2010, 2012, 2014, 2016	Current prices (% of total)	3.1
3.2 Analyze big data from any data source	2016, 2018, 2020	%	3.2
3.3 Use service robots	2018, 2020	%	3.3

Source: Authors' computation

In Table 2 we have included a representation of all indicators selected for our study, following other relevant studies (Clavino et al., 2018; Santos & Lomardo, 2019). The limitations caused by the data availability have led to discrepancies in the time dimension and sectors comparability. Thus, we have determined the evolution of the phenomenon every 2 years, starting from the first even year available and ending with the latest even year.

As previously mentioned in comparable studies, through the chosen indicators we reiterate the idea of a digital transformation built not only by investing in equipment and automatization, but also in specialists and continuous improvements through innovation and research (Clavino et al., 2018).

Results

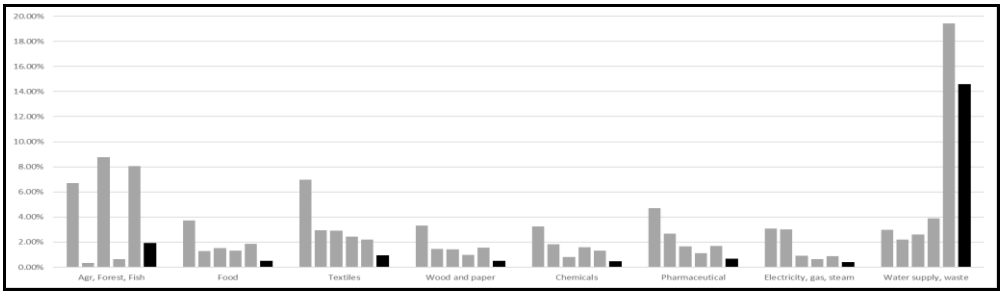
Based on the current trends in digitalization and within the limits of data availability, we have identified three main categories of technological development for a country's bioeconomy: equipment and substitutes, resource planning and security, data management, and research.

1. Equipment and substitutes

This category considers, traditionally, any computing equipment, machines and industrial robots that help the automatization of the value chain in a sector. In addition to this, we have considered cloud computing a counterpart of the previously mentioned resources in the online environment, as it replaces the physical warehouses and some of the automated processes involved.

By monitoring the status of the Romanian enterprises every two years between 2006 and 2016, we can observe in Figure 1 a significant decrease in investments in computing equipment.

Figure 1. Distribution of computing equipment, every 2 years from 2006 to 2016 in Romania (% of total assets)

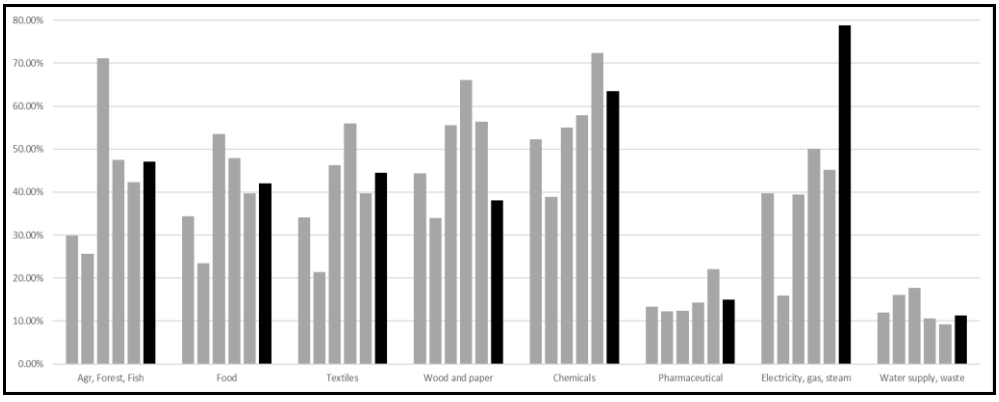


Source: Authors' computation

Note: the latest available year is highlighted in black

For the traditional sectors of the bioeconomy, this trend can be explained by the saturation of the market, all the necessary investments having been done already or are being transferred to the new derived sectors. One of the only remaining sectors that have experienced exponential growth is waste management and water supply. Over 14% of the total non-residential investment went to the equipment for managing waste and water resources, a high percentage compared to the other sectors, but a considerable decrease from the previous year.

Figure 2. Distribution of machinery and equipment, every 2 years from 2006 to 2016 in Romania (% of total assets)



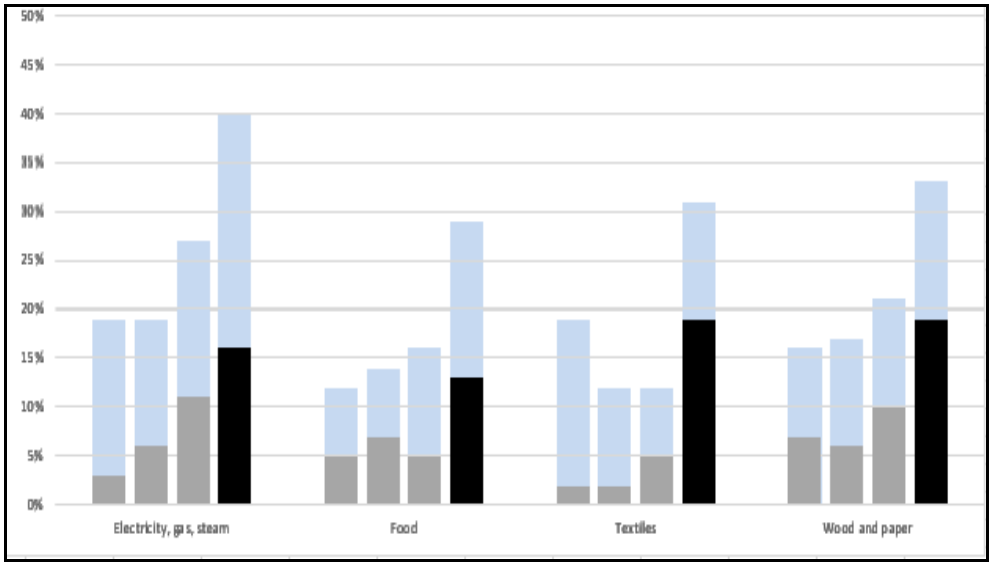
Source: Authors' computation

Note: the latest available year is highlighted in black

An improvement can be seen in Figure 2 for the machinery and other equipment indicators due to constant investments in the expansion of variate services at a national level. Amongst them, the expansion of the electricity and gas network has received more support from the authorities and has led to a relatively high percentage of investment. This increase can be explained to an extent by the increase in salaries and overall well-being, people in rural areas demanding more resources to satisfy their needs.

The investment in cloud computing has increased considerably in the past years, from less than 5% in 2014 to almost 20% in 2020. Historical data could not be retrieved as the resource has entered only in the last decade in the scope of the statistical data providers. Data for agriculture, forestry, fisheries, water supply, chemical and pharmaceutical industries was not made available by the data provider. As shown in the figure below, Romania is following the global trends in digitalization. The bioeconomy sector in terms of cloud computing services acquisition has experienced a substantial development on all its pillars such as derived sectors and services. However, this capacity is way below the European Union average (highlighted in blue) with more than a half on absolute values, forcing urgent action on balancing the discrepancy between the two entities.

Figure 3. Distribution of cloud computing services used over the internet, every 2 years from 2014 to 2020 in Romania compared to the European Union (% of enterprises)



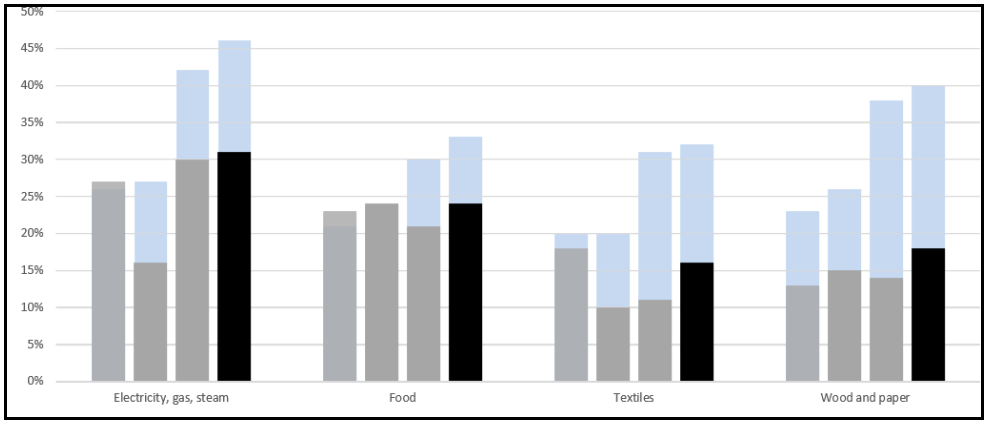
Source: Authors' computation

Note: the latest available year is highlighted in black; data for Romania is highlighted in grey and black; data for EU is represented by blue bars

2. Resource planning and security

The second category is investigating the capacity of the enterprises in a country to plan their resources and to communicate efficiently via safe digital networks. It consists of the software packages implemented to share information between departments or between the company and its clients.

Figure 4. Distribution of enterprises who have ERP software package to share information, every 2 years from 2014 to 2020 in Romania compared to the European Union (% of enterprises)



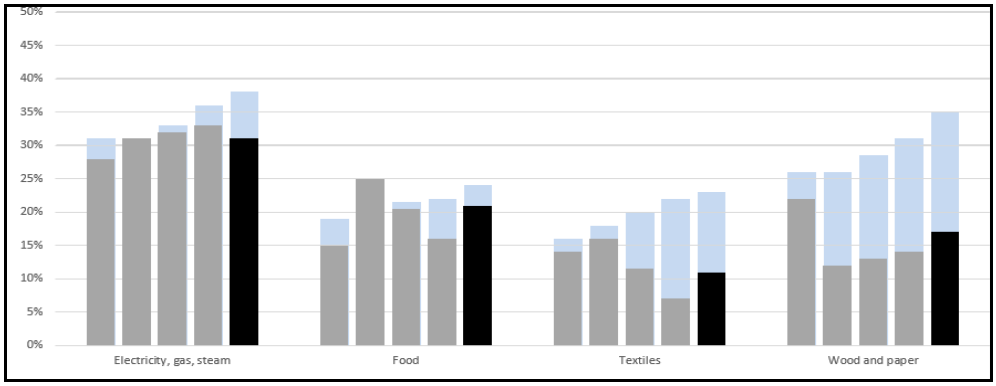
Source: Authors' computation

Note: the latest available year is highlighted in black; data for Romania is highlighted in grey and black; data for EU is represented by blue bars

The first topic to be measured is the enterprise resource planning system implementation (represented in Figure 4), which has experienced a relatively low increase in Romania since 2010. For 2016-2017, there is a margin of 15% between Romania and the European average, showing again the low performance of the country in all sectors of the bioeconomy. This phenomenon can be explained by the high number of small and medium enterprises in Romania compared to the other countries in the EU that cannot implement integrated systems as there are not feasible.

A similar picture, but with a lower variance, can be seen in Figure 5 at the enterprises that are using customer relationship management solutions. Even though Romania is having a small increase in all the analyzed sectors, the difference between it and the EU is smaller.

Figure 5. Distribution of enterprises using Customer Relationship Management (CRM), every 2 years from 2008 to 2016 in Romania compared to the European Union (% of enterprises)

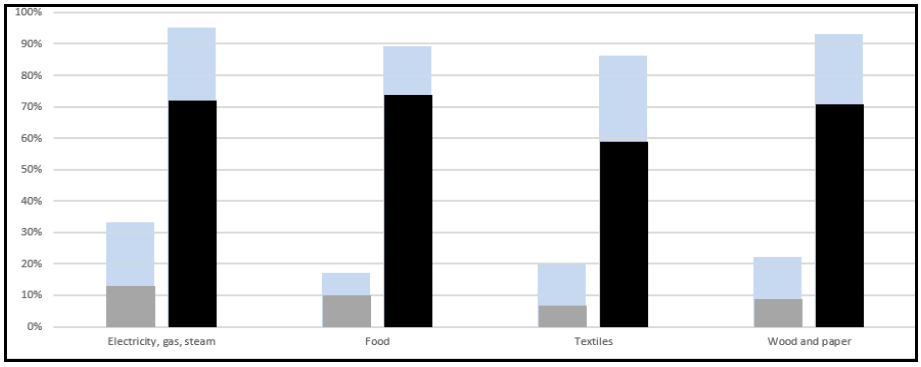


Source: Authors' computation

Note: the latest available year is highlighted in black; data for Romania is highlighted in grey and black; data for EU is represented by blue bars

Due to the numerous regulations on ITC security and data protection mechanisms, Figure 6 is pointing out the good results on a 10-year span of implementation, ensuring that over 60% of the enterprises in the textiles industry, and over 70% in the other bioeconomy sectors are having their employees' data protected.

Figure 6. Distribution of enterprises using ICT security measures for 2010 and 2018 in Romania compared to the European Union (% of enterprises)



Source: Authors' computation

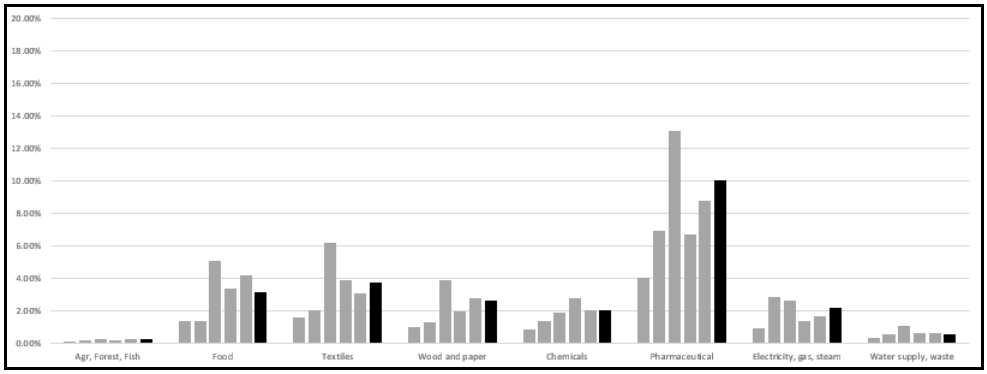
Note: the latest available year is highlighted in black; data for Romania is highlighted in grey and black; data for EU is represented by blue bars

3. Data management

Considered to be the most important driver for governance efficiency in a company, data management plays a key role in understanding the customer and its behavior, forecasting the revenue and costs, or assessing the risks. In the end, optimal management of data will lead to a considerably higher profit and share of the market.

The investments in databases have grown significantly from 2006 until nowadays in all areas, and in the most recent ones in particular, as presented in Figure 7. Therefore, the bioeconomy sectors are not far from the general trend, but we may observe unsatisfactory signs of progress in traditional domains such as agriculture, forestry, fisheries or water supply. The pharmaceutical industry took advantage of the benefits of integrating organized data flows to their business as usual. The same approach can be seen in other derived sectors as well. Even though the peak was reached in 2010, the positive trend is confirming the openness of the companies to investments in databases. A reason for these numbers might be related to the need for more software assets for their core activities. At the same time, the increasing number of biotechnology enterprises may represent another case worth to be considered.

Figure 7. Distribution of enterprises using computer software and databases, every 2 years from 2006 to 2016 in Romania (% of enterprises)

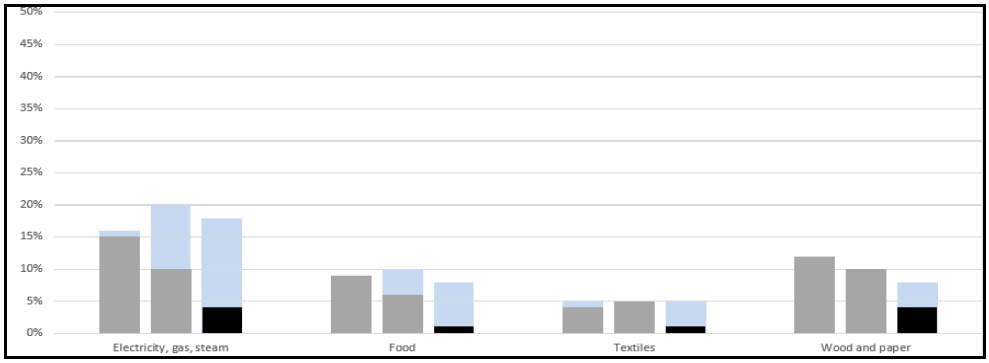


Source: Authors' computation

Note: the latest available year is highlighted in black

The digital investment that goes hand in hand with the data warehouse is big data analysis. In the past decade, we have experienced the growth of the concept as many companies have felt overwhelmed by the amount of data that needed to be processed for value-added outcomes (Figure 8).

Figure 8. Distribution of enterprises analyzing big data from any data source, every 2 years from 2016 to 2020 in Romania compared to the European Union (% of enterprises)

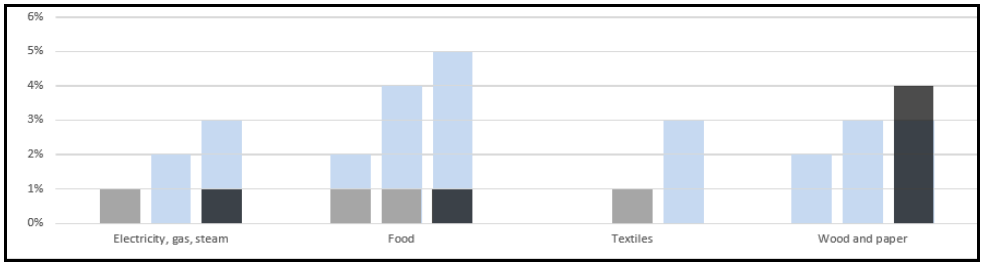


Source: Authors' computation

Note: the latest available year is highlighted in black; data for Romania is highlighted in grey and black; data for EU is represented by blue bars

However, a report published by Forbes (2020) has called into question the performance of big data implementation projects, many of them failing due to the challenges that only a few people were able to solve, the duration of such a project, or the relevancy of the initial scope after the project has been implemented. These weaknesses have led to a decrease in investments in big data analysis. A similar situation can be determined from the below figure as well. In Romania, the negative trend can be spotted since the beginning period, while in Europe there have been fluctuations throughout the years.

Figure 9. Distribution of enterprises using service robots, every 2 years from 2016 to 2020 in Romania compared to the EU (% of enterprises)



Source: Authors' computation

Note: the latest available year is highlighted in black; data for Romania is highlighted in grey and black; data for EU is represented by blue bars

As a potential benefit of investing in big data, we can emphasize the ability of a company to automatize its support services for the clients using service robots. Therefore, even if the data providers are at the beginning of their way of producing data for this case, we were able to determine a positive trend based on the existing values, at the national and regional levels.

Table 3 summarizes the digital intensity of the bioeconomy sectors in Romania for the most recent years according to the indicators considered for analysis. A green cell is associated with a value higher than the third quartile, while a red one stands for a value less than the first quartile, which means less than 25% invested in that area for the considered indicator. A white cell represents the absence of information.

For agriculture, forestry and fisheries we can observe high investments in technical equipment, a paradox compared to other states in the European Union, but which can be explained by the historical economic profile of Romania, being recognized for high productivity in these areas (Anitei et al., 2021). The food sector may seem to have good strategies for digital transformation in resource planning and digital transformation, but low performance for investments in equipment. The wood industry performs well in managing data, but its digitalization is slowed down by the other groups. For textiles, the intensity is very low in terms of resource planning systems but considerably high for the technical assets.

Table 3 - Sectoral taxonomy of digital intensity, by indicator and bioeconomy sector in Romania (the most recent year in each case)

	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3
Agr., forestry, fisheries									
Food and beverages									
Wood and paper									
Textiles									
Chemicals									
Pharmaceuticals									
Energy									
Water and waste									

Source: Authors' computation

Note: The headline aliases can be found in Table 1; legend: green – high intensity, light green – medium-high intensity, yellow – medium-low intensity, red – low intensity

While for the chemical, pharmaceutical and waste management industries it is hard to determine the intensity of the digital transformation, the energy sector seems to perform well in all areas, except for the computing equipment.

From a vertical perspective, there is no digitalization area where all the sectors are performing very well, but we can distinguish a relatively good indicator for data management investment intensity.

All things considered, two main paths can be derived and further assessed throughout sustainability and digitalization policies. The first one emphasizes the most vulnerable sectors against digital transformations that need leverage to maintain their high contribution to Romania's economic development. The focus would be on agriculture, forestry, fisheries, as well as the textile industry, water treatment and waste management. The second implication affects entrepreneurship actions and policies, and it involves the existing entrepreneur, on the one hand, who could discover the company's position in the operational area compared to other related sectors, and how many levels must be passed to secure the business. On the other hand, the future entrepreneur would be interested in the starting point for the investment sector and each branch of digitization.

Conclusions

The present study comes as a transposal of the OECD analysis on the Romanian bioeconomy (Calvino et al., 2018). The main scope was to explore the level of digital transformation of the bio-sectors of the economy between 2006 and the most recent year where the data was available. Moreover, we have assessed the intensity of digitalization based on different ITC pillars to be able to determine the strengths and weaknesses of the policies and strategies implemented in Romania, compared to other European states.

While there have been performances recorded in most of the cases, the bioeconomy industries in Romania are still far from the European average in terms of digital transformation. As highlighted through the analysis, the energy and food sectors are the fastest in developing a digitalized business model, with the wood industry and the traditional ones coming right after. A potential for streamlining data management can be suggestive for the agricultural sector, which could lead to a recovery and, implicitly, to an increase in the contribution to the national economy. There is an opportunity to be taken advantage of in the other sectors as well, mostly in data management and resource planning. The same conclusion as Santos and Lomardo (2019) can be reiterated in our paper as well, that the investment in digitalization should not consider only machines, but also others to increase the value of the organization.

Several policy implications can be highlighted as the present study can prove to be an efficient tool for the reprioritization of the sectors that aim to minimize the losses caused by the absence of reaction on the digital transformation opportunity. The strategy for a

sustainable economy and the actions taken for encouraging the entrepreneurial sector can benefit the most from the present research.

Further development could enhance the available clusters with new indicators such as interconnected systems implementation and usage, radio frequency and other state-of-the-art technologies, or by introducing a new category for research and development. Lastly, the study would benefit from a consistent database that should include all the European countries, comparable periods, and data for all bioeconomy sectors that have a corresponding entity in the system of national accounts.

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