RS Global Journals

Scholarly Publisher
RS Global Sp. z O.O.
ISNI: 0000 0004 8495 2390

Dolna 17, Warsaw, Poland 00-773
Tel: +48 226 0 227 03
Email: editorial_office@rsglobal.pl

JOURNAL	International Journal of Innovative Technologies in Economy
p-ISSN	2412-8368
e-ISSN	2414-1305
PUBLISHER	RS Global Sp. z O.O., Poland

ARTICLE TITLE	BIOECONOMY AND BIOECONOMICS: ARE THEY THE SAME THING?
AUTHOR(S)	Elena Valentina Tilica
ARTICLE INFO	Elena Valentina Tilica. (2021) Bioeconomy and Bioeconomics: Are They the Same Thing? International Journal of Innovative Technologies in Economy. 1(33). doi: 10.31435/rsglobal_ijite/30032021/7470
DOI	https://doi.org/10.31435/rsglobal_ijite/30032021/7470
RECEIVED	08 January 2021
ACCEPTED	06 March 2021
PUBLISHED	11 March 2021
LICENSE	This work is licensed under a **Creative Commons Attribution 4.0 International License.**

BIOECONOMY AND BIOECONOMICS: ARE THEY THE SAME THING?

***Elena Valentina Tilica**, PhD, Faculty of Finance and Banking, The Bucharest University of Economic Studies, Bucharest, Romania,*
ORCID ID: https://orcid.org/0000-0002-4649-3520

DOI: https://doi.org/10.31435/rsglobal_ijite/30032021/7470

ARTICLE INFO

Received 08 January 2021
Accepted 06 March 2021
Published 11 March 2021

KEYWORDS

bioeconomy, bioeconomics, sustainable growth, renewable resources, socioeconomic modeling.
JEL Classification:
Q57- Ecological Economics: Ecosystem Services; Biodiversity Conservation; Bioeconomics; Industrial Ecology

ABSTRACT

Numerous studies in academic literature study bioeconomy as part of the worldwide desire to find new or more sustainable ways to obtain economic and cultural growth. They view it as a new economic sector used to invent, promote and develop processes compatible with a durable environment. Bioeconomics has had a constant development in scientific literature in the last two centuries. It was created to link to powerful sciences: biology and economics, in an endeavor to broaden the existing theories in both disciplines or create new ones. The connection was created two-fold: using economic concepts and models to analyze biological phenomena or using a biological perspective to study economic behavior. This paper endeavors to present a brief overview of the different approaches found in literature concerning the concepts of “bioeconomy” and "bioeconomics", their similarities, differences and areas or overlap.

Citation: Elena Valentina Tilica. (2021) Bioeconomy and Bioeconomics: Are They the Same Thing? *International Journal of Innovative Technologies in Economy.* 1(33). doi: 10.31435/rsglobal_ijite/30032021/7470

Introduction. In a period when climate change and biodiversity conservation are a global hot topic, international organizations and institutions, like the European Union (EU) or the Organization for Economic Co-operation and Development (OECD) have pledged to use their resources (monetary or otherwise) in support of them. They began helping to raise awareness of the importance of these themes and, subsequently, encouraging scientists from both the academic circles (through research centers) and the practical reality (through the corporate R&D departments) to get involved. This led to a rapid increase in the literature dedicated to the development of new methods used to create economic value, while still conserving the environment. Thus, the concept of bioeconomy emerged, in the broader sense it is understood. However, this concept can be linked to numerous economic sectors and the perspectives presented in the literature on the methods to reach its goals vary significantly. In parallel, a different connection between biology and economics has been studied in literature, namely modeling economic phenomena by using biological models or, vice versa, using economic models to explain different biological phenomena. It is known as "bioeconomics".

A simple internet search in different international databases using, consecutively, as keywords "bioeconomy" and "bioeconomics" suggest that the existing literature has more interest in the former than the latter (see Table 1). However, as seen in Figure 1, a more in-depth annual analysis shows that was not always the case. Before 2000, studies regarding "bioeconomy" were very rare, the first being published around the 1970. "Bioeconomics" related papers were more common in this period, the

oldest study dating from the 1930[1]. The situation remained the same until 2011, when the heightened interest for bioeconomy lead to a higher number of published studies than the other concept. Enthusiasm connected to "bioeconomy" created an almost exponential increase in the published articles in the following years, while the momentum of "bioeconomics" remained relatively constant throughout the period.

Table 1. Keywords searches on international databases (February, 2021)

Database	Bioeconomy	Bioeconomics
Emerald	118	162
Google Scholar	51510	25593
ProQuest	7657	4767
Sciencedirect.com	3861	2736
Scopus	2480	509
Taylor and Francis	776	680

Source: author's internet searches

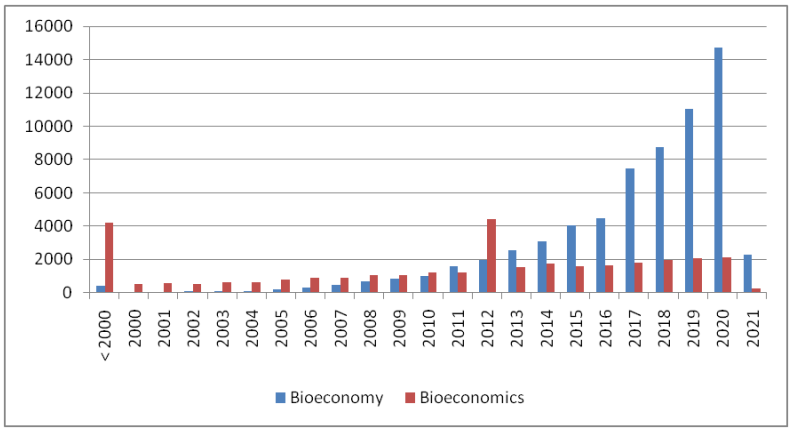

Fig. 1. Keyword based internet searches: bioeconomy vs. bioeconomics
Source: author's internet searches. The number of paper reported for 2021 include the ones published until February, 11th.

Thus, it is easy to observe that a change in paradigm announced by global international institutions, like the EU or OECD, has an important impact on the development of scientific literature. It creates incentives to obtain valuable research on the desired subject which will lead to an increase in the studies published on that topic. However, it does not necessarily lead to a decrease of papers in other areas, the academic environment striving to include both old and new research interests.

Based on existing literature, there is no sole definition given that is used by all either related to "bioeconomy" or "bioeconomics". Instead, most studies and international organizations show which definition they use when performing the analysis. For both concepts, most of the proposed perspectives have some common points, but there are still some significant differences. This study endeavors to highlight the most common perspectives envisioned by scientific literature for these concepts. Moreover, it tries to present the main differences seen between the two concepts and the area where they overlap in literature.

The remainder of the study includes a brief analysis of the existent literature linked to the "bioeconomy" concept, in section 2, and the "bioeconomics" concept in section 3. Section 4 presents the main conclusions that can be drawn from the analysis.

Concept analysis – bioeconomy. Piotrowski, Carus and Carrez (2019) show that bioeconomy has an important influence on the overall economy of the EU-28 countries. The turnover generated by this sector has increased significantly from 2008 (around 1.9 trillion Euro) to 2016 (around 2.3 trillion Euro, a 21% increase). As seen in Figure 2, the biggest contributor is the food sector which, alongside the beverages one, accounts for almost half of the turnover. Other primary sectors, agriculture and forestry,

[1] This year was found based on the ProQuest database. The other databases show similar results.

supply an additional quarter, while the bio-based industries represent the last quarter. This suggests that the interest in bioeconomy can be found in all facets of a national economic environment through the R&D programs and other strategies implemented at firms' level with the support of the governmental policies.

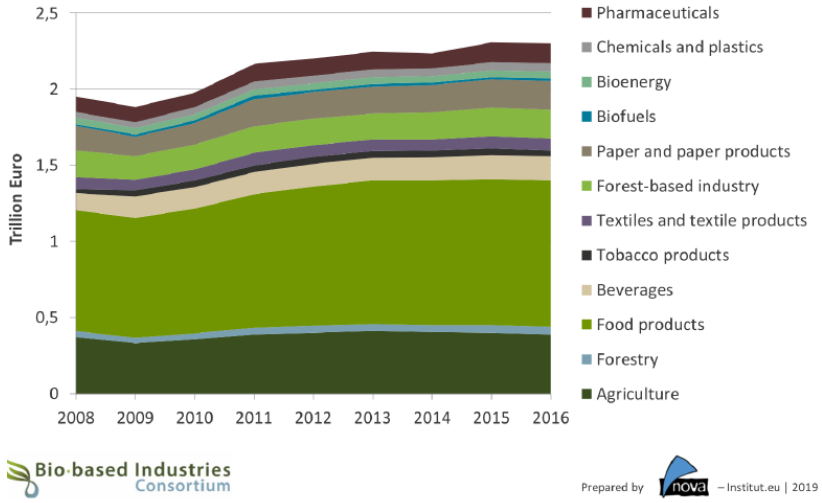

Fig. 2. Turnover in the bioeconomy in the EU-28, 2008-2016
Source: Piotrowski, Carus and Carrez (2019)

When talking about the impact of the bioeconomy sector on employment, the situation is different. The biggest employer is the agricultural sector which supplies over half of the existing jobs, followed by the food sector with around a quarter. Between 2008 and 2016, the total number of employees engaged in bioeconomy has decreased from around 20 million persons to 18.6 million (a 7% decrease), as seen in Figure 3. The agricultural sector represents the main cause of this situation, probably due to the continued effort observed in this sector to use more efficient, less complicated equipment which needs less personnel. The rest of the sectors show a stable or, even, increased numbers of employees during the analyzed period.

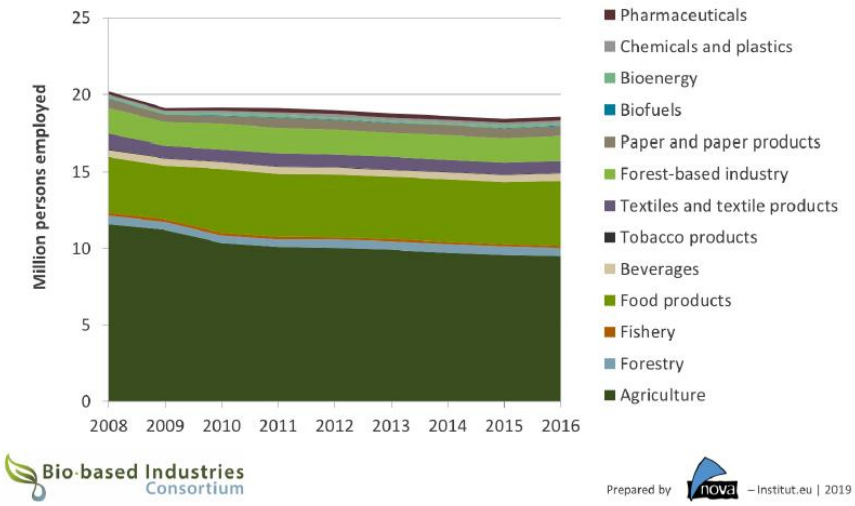

Fig. 3. Employment in the bioeconomy in the EU-28, 2008-2016
Source: Piotrowski, Carus and Carrez (2019)

Based on this analysis, it is clear that the concept of "bioeconomy" has become, especially in the last two decades, an important subject that should be taken into consideration when developing the national and European development strategies. However, due to its vast reach across multiple sectors of the economic environment, implementing a certain policy that affects one of its sectors could have consequences hard to be forecasted if not studied properly. A good starting point in this endeavour could be understanding exactly which of its sub-sectors it affects and the theoretical and practical connections it has to the other sectors. For this, the existing scientific literature offers a good overview of the different perspectives of the concept of "bioeconomy" and its implications.

According to the German Bioeconomy Council (2015) “Bioeconomy is the production and utilization of biological resources - including knowledge - to provide products, processes and services in all sectors within the framework of a sustainable economy.” Von Braun (2018) supports this statement by explaining that it stands for more than just using biomass for energy. He explains that this trend for bioeconomy became global because it fulfils the worldwide need to surpass the “constrains related to climate, water, energy and land” and new consumer preferences. In line with these considerations, the Global Bioeconomy Summit (2015) suggested that the related programs should not be fragmented, but used in parallel to support a higher and more stable development of bioeconomy.

The European Commission (EC) views bioeconomy as a specialized branch in economy that whose main goal is to produce renewable resources. Additionally, it should transform them, alongside the resulted waste, into useful products, like biofood, bioenergy or biofuel (European Commission, 2012). OECD provides a similar definition by which bioeconomy is "the set of economic activities linked to the invention, development, production and use of biologic products and processes". Its goal is to enhance population health, productivity of the agricultural and industrial sector, while still maintaining a sustainable environment (Arundel and Sawaya, 2009).

This concept has gained momentum due to the important changes generated by the high globalization of this century, like the climate changes, the abrupt economic recession, the worldwide increase in population and the use of, mainly, non-renewable resources whose diminishing reserves pose a serious long-term threat. The need to find sustainable methods to maintain a positive trend of economic and cultural development led to the inclusion of this purpose in national or even international public strategies. This includes the objectives of corporations from different industrial sectors and of academic pursuits (Carlo Ingrao et al., 2016).

Priefer, Jorissen and Fror (2017), having studied over 65 related papers, observed that, generally speaking, there is a consensus concerning the main goals of bioeconomy. However, the proposed methods of achieving them are different and, usually, focus on different economic sectors, like new technologies, consumer behavior or efficient use of resources. The authors suggest that these should be pursued simultaneously, at least until it is clear which one of them will bring a higher benefit to the community.

Bioeconomy can be seen as an alternative solution for a continuous economic development, while simultaneously reducing the environmental degradation. However, caution is needed because its defining factors are numerous and complex. For example, connections have to be made between economic sectors that were independent before (e.g. agriculture, the chemical sector, public food or energy sector). Thus, different groups of stakeholders, which presumably have opposing objectives, have to learn to work together to identify the best opportunities (Lewandoski, 2015).

Another potential problem comes from the geographical exposure of the phenomenon. In order to reach the goals of bioeconomy, numerous social and legal changes will be needed at a national level. However, these should be connected at an international level to maximize their effect. Thus, this cultural reshaping will need time and will be interrupted by numerous obstacles, both technical and political. (Philp, 2005).

Dalia D'Amato et al. (2017) study the concepts of "green economy", "circular economy" and "bioeconomy", as possible exponents in the development of public strategies of sustainable growth. They show that these concepts are similar, but not identical in meaning, as they cover different areas. Green economy is a wider concept, that includes activities from circular economy, from bioeconomy and, also, other similar ones. However, they note that the research connected to all of these three concepts is related to sustainable sectors and, with a smaller impact, to national or regional economic growth. Pavliashvili and Gubeladze (2020) apply the principles of a circular economy to create a model for agricultural production. They show that is can be a more economically effective alternative to the traditional linear economy.

Dalia D'Amato et al. (2017) link the inception of the concept of bioeconomy to the research of Georgescu-Roegen (1975), however they mention that its definition has suffered modifications in time. According to them, the current perspective is that the raw materials used in the industrial sector should be made from renewable bioresources. At the core of this transformation process should be the R&D departments.

By analyzing more than 1800 papers published after 1990 which included as keywords at least one of the three: green economy, circular economy and bioeconomy, they observed a high increase in

their popularity after 2000. Moreover, bioeconomy is preferred in Europe, which the authors link to the EU strategy that promotes the concept. (European Commission, 2012). The concept of green economy is more present on the American continent, while in Asia bioeconomy has started to gain momentum.

Devaney and Henchion (2018) study bioeconomy, as seen by the European Commission, as a result of the important debates which emerged in the international political area. They use a Delphi qualitative methodology that implies various rounds of questionnaires sent to the same recipients. They used two rounds which were sent to experts in the area of bioeconomy. The questions were related to their opinion regarding the development perspectives of bioeconomy in Ireland for different sectors (horticulture, protein extraction from marine sources, use of algae in food preparation, etc.). The methodology allowed in the second round for experts to change their answers from the first round of questionnaires. Additionally, they could offer evidence for or against the opinions given by other experts in the first round.

Based on the answers they received in both rounds, the authors observed some common points of view and, also, numerous differences between the goals of the bioeconomy, seen in the broad sense, given by the experts. Thus, they conclude that several conditions need to be met in order to fulfil the objectives regarding an economic and social development which also includes a sustainable use of the environment. First, the process used should be highly innovative (thus, needing great innovations) both at a technical level and regarding the collaborative aspects between these sectors. Additionally, the implementation of a strict, objective and impartial governance is essential in order to maximize the objectives of every stakeholder without hurting the others or the end result.

Maes and Passel (2019) study bioeconomy seen as a segment that uses new bio-technological applications. This branch is supported by the EU through a variety of programs that encourages the R&D activities and offers different forms of subsidies (European Commission, 2018). A similar strategy is also employed by the OECD (Arundel and Sawaya, 2009). However, a critical limitation of this branch is the fact that it is dependent on the use of biomass as raw material. For this reason, Maes and Passel (2019) study the impact of this limitation on the efficiency of different policy measures taken to support the development of this segment. They use a methodology that simulates the impact of three different measures on the development of a new sector of biochemistry (e.g. manure processing in Belgium). Their results show that the measures will have an impact on the long-term evolution of the sector. However, its degree of development is highly susceptible to the availability of raw materials (biomass) at the right moment.

The availability, at least as a theoretical level, of biomass residuals is, also, the research topic of Hamelin, Borzecka, Kozak and Pudelko (2019). The authors propose a methodological approach that quantifies the total theoretical volume of the potential biomass residual available in each micro-region (according to the NUTS-3 classification) from the EU-27 member states. Four distinct sectors were included as elements of biomass: agriculture, forestry, urban greenery management and food waste. Their results show that these residuals could cover the annual need for energy in both Italy and Belgium. Moreover, their methodology permits cataloging each type of available residual and its probable location. Thus, they observed that the main sources for residuals are the forestry sector and straw from the agricultural sector. Additionally, they individualized the areas with the highest potential for biomass residual: the regions of Paris (France) and Jaen (Spain), which have the highest density of biomass.

Efken, Dirksmeyer, Kreins and Knecht (2016) study the importance of bioeconomy in the German economic sector between 2002-2010. Their definition of bioeconomy, which is in line with the one of the German Bioeconomy Council, states that it includes all sectors and services that use or develop biological resources of any kind. Thus, the authors include in their analysis different industrial sectors like: agriculture, horticulture, forestry and fisheries, and determine the importance of bioeconomy in any given sector based on indicators like the number of employees or the gross added value. Their results show a significant increase of the impact of bioeconomy between 2002 and 2010, culminating with a percentage of over 10% of the total number of employees and the gross added value represents about 6% of GDP.

The articles presented until now are only a small fraction on the vast array of papers concerned with the analysis of bioeconomy. One of the main topics that can be observed among these is linked to providing a clear and objective definition of the concept and other close-related ones (e.g. D'Amato et al, 2017, Priefer et al., 2017, McCormick and Kautto, 2013, von Braun, 2018). This highlights the worldwide importance given to this subject and that the academic circle is invested in founding the common ground of all the existing perspectives and reaching a consensus.

This situation is also observed by Bugge, Hansen and Kliykou (2016) by studying over 40 papers concerned with bioeconomy. The authors show that academic literature related to bioeconomy can be classified in three major groups, based on their approach: articles studying bio-technology, the ones concerned with bioresources and the ones with bio-ecology. However, they insist that these approaches are not completely separated, but, instead, can be viewed as ideal representations of what bioeconomy could mean.

Bio-technology (based on the definition given by OECD) highlight the importance of researching, developing and using bi-technology in different sectors of the economy. Its main purpose is to create economic growth and new jobs, but this can only be achieved through an increased cooperation between the academic and technological sectors. Bioresources (supported by the European Commission) aim to create a sustainable economic growth through R&D activities linked primarily with renewable resources (bioenergy, biofood). This approach is based on highly innovative processes and a powerful interaction between different sectors. The last approach, bio-ecology, is meant to improve ecologic processes and promote biodiversity. In this case, economic growth is less important, seen as a byproduct of the increases of the ecological methods in the business sector.

Based on the vast areas that bioeconomy covers, it is easy to understand why the methods used to study it vary significantly. As seen before, analyses can be made using qualitative methods (Devaney and Henchion, 2018) or quantitative ones (Efken et al., 2016). This suggest that a potential for new research still exists which could lead to observing the impact that bioeconomy has on the development of the economic sector. Moreover, the strategic policies meant to support it have started to be implemented in multiple countries around the world (especially in Western Europe and USA) after 2000. Thus, their effects should be already visible and quantifiable.

Concept analysis – bioeconomics. In parallel with the rapid development of the scientific and practical interest in "bioeconomy", the "bioeconomics" topic has maintained its momentum in academic literature. Even though their names are similar, their applications are, usually, very different. An overview of the usage and applications of the two concepts (bioeconomy and bioeconomics) is given by Zawojska and Siudek (2016).

Presumably, the terminology of bioeconomics was introduced by Reinheimer (1913) and his definition was related to the study of the way different organisms are integrated in "nature's economy", highlighting the existing division of labour. The link between biological systems and the economic process can also be seen in Georgescu-Roegen (1977). A more detailed description of the author's work and the dissensions it created are presented in Gowdy and Mesner (1998). Following the same perspective, Mohammadian (2003) defines bioeconomics as a branch of economy that investigates "the socioeconomic system in conjunction with the biological system as a whole" and studies "the non-linear interactions between their components".

According to Landa and Ghiselin (1999), bioeconomics uses economics and biology "for the purpose of enriching both disciplines" by creating new models, "theories and paradigms". They suggest that biology has strong connections with economy through the various economic terminology used in biology and, also, theoretical models (e.g. linked to ecological and environmental economics). However, the authors posit that problems could arise if the link is not researched with causation as organisms rarely react the same to external factors, as is the main assumption for most economic models.

The economic environment has become more and more complex in time, which led to the increased awareness of the concept in the academic circles due to its applicability in this state of development. Ghiselin (2000) provides a bibliography of around one thousand studies that can be linked in a higher or lower extent to economics and biology. These span a long time period, starting in the late 1800' s, and cover a wide array of subjects: anthropology, psychology, evolutionary economics, game theory, conservation and resource management, among others.

According to Witt (1999), bioeconomy is "the merging of biology and economics" which means that it includes a two-way link between them. On one hand, it leads to the export of the logic and optimization processes used in economic modelling to biological situations. On the other hand, it consists in using a biological approach to explain different economic phenomena (a view that is also depicted in Zawojska and Siudek, 2016).

The first link described by Witt (1999) can be observed in a multitude of other papers that target different economic processes and various biological aspects. For example, Corning (2018) focuses on the Synergism Hypothesis which starts from an economic cost and benefits model applied to the natural

selection process of living systems. It provides examples that support the idea that the synergies that appear between different individuals are the cause of the "evolution of complex living systems over time".

The second link presented in Witt's paper (1999) is the main focus of the author. In the beginning, he explains why the Darwinian revolution from biology could be used to also start a "new paradigm in economic theory". Additionally, he explains how economists could and have borrowed several concepts from the Darwinian evolutionary theory (e.g. natural selection). Zawojska and Siudek (2016) support this statement and suggest that other important concepts from economics have been taken from the studies of biological systems: scarcity of resources, market signalling or "the logic of collective action".

Studies pertaining to be part of this second perspective target various basic economic concepts through different approaches. Gifford (2000) takes into account the concept of altruism by studying individuals' behaviour in economic environments where "transactions and information are costly" and trading is not simultaneous. Due to these constraints, harmful behaviours might appear (e.g. opportunistic behaviour, free-rider problem, moral hazard). In order to protect themselves, individuals choose to cooperate and adhere to institutional rules. Thus, institutions become the main focus of analysis as it becomes inseparable to "individual gains". In biology, a similar pattern can be discerned in different animal societies governed by cooperation. Thus, "group level analysis" is also needed in order to observe the structures of institutions made to deter from harmful behaviours.

Getty (2004) proposes an alternative to US national accounts by redefining concepts like consumption, profit or investment return. He differentiates between maintenance consumption and consumption for human capital improvements. He shows that productivity gains lead to national accounts growth and that thrift is a natural biological instinct, not a policy to stimulate growth.

Harper (2008) studies an economic agent's capacity to represent the "sizes of sets of economic goods" through different biological and economic characteristics. They found that "systematic numerical cognition" (which is specific to the human brain) in combination with the monetary trading concept helps condense a complex information dataset into a number: the goods' price. Thus, through this biological component "entrepreneurs can compute the profitability of past ventures" or decide future investments policies.

Tanure, Nabinger and Becker (2013) create a bioeconomic model to support the decision-making process in farm production systems. They take into account "inter-related economic and biological components" and generate strategies which include both economic results, an environmental impact assessment and an operational risk analysis.

Jaffe et al. (2014) study "bioeconomics aspects of shame and guilt" from a cultural, linguistic and quantitative perspective. They found that no overlapping synonyms can be found for "shame" and "guilt" in any language and that most languages have more synonyms for "shame". Additionally, there is a strong correlation between the number of shame and guilt synonyms and the estimated "corruption and ease of doing business". They consider that these results show that the typical biological evolution was continued through a cultural one. Thus, they suggest that biological aspects, cognition and emotional traits should be investigated further to better understand human economic behavior.

Srivastava, Sharma and Srivastava (2019) focus on neurofinance, as a niche in the vast bioeconomics domain. They present a compelling depiction of existing literature linking human brain activity to the financial decision process. They suggest additional real-life, empirical studies should be performed to observe the importance of including neuroimaging techniques, alongside psychology in explaining human behavior while making financial decisions.

A special category of papers are studies that combine "bioeconomy" and "bioeconomics". They use typical economic-related indicators and processes to analyze the biological concepts of "bioeconomy". Conrad (1999) develops a stochastic approach to determine if marine sanctuaries could be used as hedging strategies against resource uncertainty. Thus, he employs economic and statistic-related terms (e.g. "present value of net revenues", "diffusion process", "standard deviation", "coefficient of variation") in order to study typical bioeconomy-related concepts ("biomass", "migration" patterns, "effect of fishing").

Hilsenroth, Grogan and Frazer (2021) assess the economic impact of changing seawater conditions (due to climate change) on black pearl production. They use a stochastic-dynamic bioeconomic simulation over a 10 year period in order to estimate a classical economic indicator (net present value). Their results show that developing production strategies by taking into account the increases in seawater temperature reduces economic losses.

Similar bioeconomic approaches can be observed in connection to other aspects connected to bioeconomy: renewable resources (Wilen, 1985, Jerry and Raissi, 2002), fisheries (Clarke, Yoshimoto and Pooley, 1992, Kvamsdal, Maroto, Moran and Sandal, 2017, Mota, 2020). Presumably, this is one of the reasons that lead Birch and Tyfield (2013) to consider the concept of "bioeconomics" as a byproduct of studying "bioeconomy" in academic literature.

Conclusions. Bioeconomy is one of the main topics of research in current literature and a multitude of approaches can be observed regarding its development. Its main purpose is to invent, promote and develop new and improved technological processes that sustain biodiversity and a durable, less invasive economic environment. The purpose of this paper was not to present every research method linked to this topic, but to highlight the various approaches used to study it. This diversity is easily explained, based on the numerous economic areas it has an impact on, related to both the human society and natural processes. In recent years, this type of research has gained much support from international organizations (EU, OECD) in their effort to help develop a more sustainable economic growth.

Bioeconomics is a topic with a relative constant presence in scientific literature in the last two centuries. Its purpose is to link two of the most important sciences developed by humankind: biology and economics, in order to develop them. Thus, new models and theories could emerge to better understand both the economic processes and biological evolution patterns. Bioeconomics-related literature can be split in two main directions. The first consists in using economic approaches to better explain biological situations. The second employs biological concepts to enhance the understanding of different economic situations.

It is highly visible that these two concepts cover different aspects of the link between "biology" and "economics". However, some studies can be connected to both, as they use a bioeconomics-related approach to study bioeconomy-related concepts. This fact can be easily explained when considering that, in fact, the bioeconomy sector is part of the economic environment. Furthermore, its impact is increasing due, in part, to the continued effort and investments made by international organizations to develop it. While this trend continues, scientific research and literature will need to keep studying it, using all possible methods, including the ones related to bioeconomics.

The purpose of this paper was not to present a comprehensive literature review on the two concepts. Given the high interest they receive and the vast area of expertise they imply, this task could prove impossible. Instead, the purpose is the present a brief explanation of the two concepts, their similarities and differences. As further direction of study, it might prove useful to better investigate the areas where these concepts overlap. This could provide additional insight in the further development of the bioeconomy sector, with implications in the real economy, and understanding of the decision-making process, with implications in the financial environment.

Acknowledgment. The author wishes to thank professor Victor Dragota for the very useful comments. The remaining errors are the author's.

Declaration of Interest Statement. No potential conflict of interest was reported by the authors.

REFERENCES

1. Arundel A. and Sawaya, D. (2009) "The bioeconomy to 2030: Designing a policy agenda", *OECD*, 2009, https://doi.org/10.1787/9789264056886-en
2. Birch, K. and Tyfield, D. (2013) "Theorizing the Bioeconomy: Biovalue, Biocapital, Bioeconomics or . . .What?", *Science, Technology and Human Values*, vol 38, 299-327, https://doi.org/10.1177/0162243912442398
3. von Braun J. (2018) "Bioeconomy- The global trend and its implications for sustainability and food security", *Global Food Security*, vol 19, 81-83, https://doi.org/10.1016/j.gfs.2018.10.003
4. Bugge M., Hansen T. and Kliykou A. (2016) "What is the bioeconomy? A review of the literature", Sustainability, vol 8, 691-714, https://doi.org/10.3390/su8070691
5. Clarke, R., Yoshimoto, S. and Pooley, S. (1992) "A bioeconomic analysis of the northwestern Hawaiian Islands Lobster Fishery", *Marine Resource Economics*, vol 7, 115-140, https://doi.org/10.1086/mre.7.3.42629029
6. Conrad, J. (1999) "The bioeconomics of marine sanctuaries", *Journal of Bioeconomics*, vol 1, 205-217, https://doi.org/10.1023/A:1010039031324
7. Corning, P. (2018) "Synergy and the bioeconomics of complexity", In: Morales A., Gershenson C., Braha D., Minai A., Bar-Yam Y. (eds) *Unifying Themes in Complex Systems IX*. ICCS 2018. Springer Proceedings in Complexity. Springer, Cham. https://doi.org/10.1007/978-3-319-96661-8_2

8. D'Amato, D., Droste, N., Allen, B., Kettunen, M., Lahtinen, K., Korhonen, J., Leskinen, P., Matthies, B.D. and Toppinen, A. (2017) "Green, circular, bio economy: A comparative analysis of sustainability avenues", *Journal of Cleaner Production*, 2017, vol 168, 716-734, https://doi.org/10.1016/j.jclepro.2017.09.053
9. Devaney L. and Henchion, M. (2018) "Consensus, caveats and conditions: International learnings for bioeconomy development", *Journal of Cleaner Production*, vol 174, 1400-1411, https://doi.org/10.1016/j.jclepro.2017.11.047
10. Efken J., W. Dirksmeyer, P. Kreins and M Knecht (2016) "Measuring the importance of the bioeconomy in Germany: Concept and illustration", *NJAS-Wageningen Journal of Life Sciences*, vol 77, 9-17, https://doi.org/10.1016/j.njas.2016.03.008
11. European Commission (2012) "Innovating for sustainable growth: a bioeconomy for Europe", *Industrial Biotechnology*, vol 8, 57-61, http://doi.org/10.1089/ind.2012.1508
12. European Commission (2018) "A sustainable Bioeconomy for Europe: strengthening the connection between economy, society and the environment", Updated Bioeconomy Strategy
13. Georgescu-Roegen N. (1975) "Energy and Economic myths", *Southern Economic Journal*, vol 41, 347-381
14. Georgescu-Roegen, N. (1977) "Inequality, Limits and Growth from a Bioeconomic Viewpoint", *Review of Social Economy*, vol 35 (3), 361-375
15. German Bioeconomy Council (2015) “Bioeconomy Policy (Part II): Synopsis and Analyses of National Strategies Around the World” Office of the Bioeconomy Council, Berlin
16. Getty, G. (2004) "Duplication, growth and 'Total return economics'", *Journal of Bioeconomics*, vol.6, pp.3-38, https://doi.org/10.1023/B:JBIO.0000017367.90924.d4
17. Ghiselin, M. (2000) "A bibliography for bioeconomics", *Journal of Bioeconomics*, vol. 2, pp. 233-270, https://doi.org/10.1023/A:1012282814475
18. Gifford, A. (2000) "The bioeconomics of cooperation", *Journal of Bioeconomics*, vol. 2, pp. 153-168, https://doi.org/10.1023/A:1011466701827
19. Gowdy, J. and S. Mesner (1998) "The evolution of Georgescu-Roegen's bioeconomics", *Review of Social Economy*, vol. 56(2), 136-156
20. Hamelin L., M. Borzecka, M. Kozak and R. Pudelko (2019) "A spatial approach to bioeconomy: Quantifying the residual biomass potential in the EU-27", *Renewable and Sustainable Energy Reviews*, vol 100, 127-142, https://doi.org/10.1016/j.rser.2018.10.017
21. Harper, D. (2008) "A bioeconomic study of numeracy and economic calculation", *Journal of Bioeconomics*, vol. 10, pp. 101-126, https://doi.org/10.1007/s10818-008-9035-8
22. Hilsenroth, J., K. Grogan and T. Frazer (2021) "Assessing the effects of increasing surface seawater temperature on black pearl production in French Polynesia: A bioeconomic simulation", *Ecological Economics*, vol. 181, https://doi.org/10.1016/j.ecolecon.2020.106914
23. Ingrao C., J. Bacenetti, A. Bezama, V. Blok, J. Geldermann, P. Goglio, E. Koukios, M. Lindner, T. Nemecek, V. Siracusa, A. Zabaniotou and D. Huisingh (2016) "Agricultural and forest biomass for food, materials and energy: bio-economy as the cornerstone to cleaner production and more sustainable consumption patterns for accelerating the transition towards equitable, sustainable, post fossil-carbon societies", *Journal of Cleaner Production*, vol 117, 4-6
24. K. Jaffe, A. Florez, M. Manzanares, R. Jaffe, C. Gomes, D. Rodrigues, and C. Achury (2014) "On the bioeconomics of shame and guilt", *Journal of Bioeconomics*, vol.17, pp.137-149, https://doi.org/10.1007/s10818-014-9189-5
25. Jerry, M and N. Raissi (2002) "The optimal strategy for a bioeconomical model of a harvesting renewable resource problem", *Mathematical and Computer Modelling*, vol. 36, pp.1293-1306
26. Kvamsdal, S., J. Maroto, M. Moran and L. Sandal (2017) "A bridge between continous and discrete-time bioeconomic models: Seasonality in fisheries", *Ecological Modelling*, vol. 364, pp. 124-131, https://doi.org/10.1016/j.ecolmodel.2017.09.020
27. Landa, J.T and M. Ghiselin (1999) "The emerging discipline of bioeconomics: aims and scope of the Journal of Bioeconomics", *Journal of Bioeconomics*, vol 1, 5-12, https://doi.org/10.1023/A:1010099821123
28. Lewandoski I. (2015) "Securing a sustainable biomass supply in a growing bioeconomy", *Global Food Security*, vol 6, 34-42, https://doi.org/10.1016/j.gfs.2015.10.001
29. Maes D. and S. V. Passel (2019) "Effective bioeconomy policies for the uptake of innovative technologies under resource constraints", *Biomass and Bioenergy*, vol 120, 91-106
30. McCormick K and Kautto N. (2013) "The bioeconomy in Europe: An overview", *Sustainability*, vol. 5, 2589-2608, https://doi.org/10.3390/su5062589
31. Mohammadian, M. (2003) "What Is Bioeconomics: Biological Economics?" *Journal of Interdisciplinary Economics*, vol *14*(4), 319–337.
32. Mota, R. (2020) "Fishery harvest control rules from bioeconomic optimization", *Marina Policy*, vol. 115, https://doi.org/10.1016/j.marpol.2020.103865
33. Pavliashvili S., Gubeladze D. (2020) "Linear economy and circular economy - current state assessment and future vision", *International Journal of Innovative Technologies in Economy*, 5(32), 1-4, doi:10.31435/rsglobal_ijite/30122020/7286
34. Philp J. (2018) "The bioeconomy, the challenge of the century for policy makers", *New Biotechnology*, vol. 40, 11-19, https://doi.org/10.1016/j.nbt.2017.04.004

35. Piotrowski, S., M. Carus and D. Carrez (2019) "European Bioeconomy in Figures 2008-2016", *NOVA Institute for Ecology and Innovation*, available at: biconsortium.eu
36. Priefer C., Jorissen J. and Fror O. (2017) "Pathways to shape the bioeconomy", *Resources*, vol 6, 2-23, https://doi.org/10.3390/resources6010010
37. Reinheimer, H. (1913). Evolution by Co-operation: A Study in Bio-economics. London: Kegan Paul, Trench, Trubner and Co., p. 200.
38. Srivastava, M, G. Sharma and A. Srivastava (2019) "Human brain and financial behavior: a neurofinance perspective", *International Journal of Ethics and Systems*, vol. 35, pp 485-503
39. Tanure, S., C. Nabinger and J. Becker (2013) "Bioeconomic model of decision support system for farm management. Part I: Systemic conceptual modeling", *Agricultural Systems*, vol.115, pp.104-106, https://doi.org/10.1016/j.agsy.2012.08.008
40. Wilen, J. (1985) "Bioeconomics of renewable resource use", *Handbook of Natural Resource and Energy Economics*, vol 1, 61-124,
41. Witt, U. (1999) "Bioeconomics as economics from a Darwinian perspective", *Journal of Bioeconomics*, vol 1, 19-34, https://doi.org/10.1023/A:1010054006102
42. Zawojska A. and Siudek T (2016) "Bioeconomics as an interdisciplinary science", Proceedings of the 2016 International Conference "Economic Science for rural development", vol 41, 273-280