Mariusz Maciejczak

Warsaw University of Life Sciences – SGGW, Poland

HOW TO ANALYZE BIOECONOMY?

JAK ANALIZOWAĆ BIOGOSPODARKĘ?

Key words: bioeconomy, bioeconomy model, analytical framework
Słowa kluczowe: biogospodarka, model biogospodarki, ramy analityczne

Abstract. The paper is an attempt to describe theoretical foundations, scope with boundaries as well as a framework for analysis of emerging concept of bioeconomy. Based on the literature review and complex system theory and contextual theory there was proposed a holistic approach to perceive dimentions of bioeconomy system and ways to analyse them.

Introduction

The term and issues of bioeconomy are increasingly becoming one of the most popular on policy and research agenda worldwide. Its importance has been shown by the direct strategic goals and allocated to them resources to finance their implementation in international, regional and local scales. The United Stated White Paper on Bioeconomy [*National Bioeconomy Blueprint* 2012] as well as the European Union policy papers [*Innovating for Sustainable*... 2012] as only two transparent examples, show that the issue is not just a semantic fashion. Also the expectations to the First Global Bioeconomy Summit to be held in Berlin at the end of 2015 calls for significant increase of the researches on bioeconomy and bioeconomy related issues [Global Bioeconomy Summit 2015]. This call is echoed by the challenges and needs related to the education of students at becoming a newly opened and attracted specializations in bioeconomy at many, not only European, universities (i.e. SGGW-WULS, University of Gent, Iowa State University, Michigan State University). However as rather new concept bioeconomy does not have one well established and commonly recognized definition and boundaries. The definitions vary, providing different perspectives of perceiving this increasingly growing and rapidly changing phenomena [Ratajczak 2015].

From one perspective, todays bioeconomy is already a large system that binds together natural resources, technologies, markets, people and policies. It actively establishes links between industries, both old, that for a long time form a chain of added values and new, that previously had no connections, within a new, symbiotic relationship where one industry utilizes the by-products of another. It is argued [see Manninen et al. 2014] that bioeconomy brings together processes that have far been disparate: business and sustainability, ecosystem services and industrial applications, innovations and technologies, biomass and products, all for mainstream economies in order to meet growing consumers' expectations. As such bioeconomy is perceived very holistically in a wide systemic approach. There are also more narrow approaches, which focus bioeconomy to the utilization of biotechnology in a given regulatory framework for different industries purposes [Takács, Takács-György 2013, Zilberman et al. 2013, *The Bioeconomy to 2030*... 2009, Harfouche et al. 20014] or development of institutional strategic approaches to meet the poverty, sustainability or climate change challenges [*Nordic Bioeconomy* 2015, Birch et al. 2010, Renssen 2014, Takacs et al. 2012].

From the point of view of social sciences, especially the economy, there are difficulties to distinguish what already is and what is not bioeconomy [Birch, Tyfield 2012]. This implies not only problems in defining the boundaries of what is called bioeconomy as a generic term, but also challenges to implement appropriate theoretical frameworks and analytical instruments to cover the complexity of this immature and diversify socio-economic phenomena.

Objectives, methods and data sources

The paper aims to make an attempt to describe the boundaries of bioeconomy from the economic perspectives as well as to develop a conceptual framework for its analysis. The presented researches are based on the secondary data sources, applying the mainstream and heterodox economic concepts into the analytical framework of complex adaptive system theory and contextual analysis driven by the holistic approach of deductive and descriptive reasoning.

Complexity results from the inter-relationship, inter-action and inter-connectivity of elements within a system and between a system and its environment. Complexity economics is considered as a mirror inversion of neoclassical theory. Complex adaptive systems from economic perspective are characterized by three main factors. Firstly, the complex economy is never in equilibrium, but is constantly subjected to shocks, both exogenous and endogenous, that affect its short-term movements. Thus, there are frequent local nonlinear resonances that lead to significant deviations of economic variables (prices, quantities, wages, asset prices) from their equilibrium values even in the absence of strong or systematic perturbations to the system. Secondly, the classical law of one price fails, and there are observed short term price deviations. Finally, complex adaptive systems rarely, if ever, achieve the sort of optimality that can be attained in simple engineered systems [Miller, Page 2007]. It is explained by Foster [2004] why it is necessary to approach economic analysis from a network, rather than a production and utility function perspective, when one deals with complex systems. It is argued that dynamic systems are able to adapt in and evolve with a changing environment. As outlined by Chan [2001] this concept stress out that there is no separation between a system and its environment in the idea that a system always adapts to a changing environment. Rather, the concept to be examined is that of a system closely linked with all other related systems making up an ecosystem. Within such a context, change needs to be seen in terms of co-evolution with all other related systems, rather than as adaptation to a separate and distinct environment.

Accordingly, in the economic literature the contextual economics has been shaped by a determination to embed economic understanding in the physical and the social contexts within which economies operate [Chan 2001]. In this respect especially the ecological context has recently posed severe challenges to the mainstream - neoclassical economics. It has tended to proceed as if economic systems operated in a physical vacuum. Raw materials are purchased from those who have property rights over them. Natural resources are invisible in neoclassical economic theory until they appear as property, when they are processed, sold, consumed, and finally disposed of. Where they come from and where the waste products go have only recently been recognized as topics of concern [Altmann 2011]. Also the historical and technological contexts should be taken into considerations as they explain the contemporary experience in light of the technological, managerial and other changes. The paper will include also political and institutional contexts as well as their behavioral implications.

Theoretical foundations of bioeconomy

The bioeconomy should not be considered neither as brand new economic pehomena, nor a new discipline within social sciences or a new sector of the economy. Rather it should be perceived in from the complex adaptive system theory perspective. The bioeconomy creates a new dimension within existing elements of the socio-economic system, in which on the large scale the progress in various forms, especially biological and technical is created, as well as product and process innovations are successfully introduced. However the originality of this phenomena, that makes the distinction, comes from to two main factors: sustainability and efficiency of renewable resources. These two factors creates a room for development of main theoretical foundations of the bioeconomy.

First driver is focused on the concept of sustainability. As it has been shown by Pfau et al. [2014] in their literature review many publications state that sustainability should be a central topic on the research agendas for the bioeconomy or even be the goal of bioeconomy development. As argued by Gołębiewski [2013] even though the bioeconomy might contribute to a more sustainable

future in various ways, a positive impact is not exactly self-evident. If sustainability is, however, considered as a central goal of the bioeconomy, there may be a good chance of achieving a positive environmental and social impact, while ensuring economic growth through innovative products and the preservation of traditional sectors, such as food production. The economic outputs also may create social benefits. It is also important to consider the interrelationship between various sectors participating in a bioeconomy.

However it should be noted that primary assumptions to the sustainability approach in the economy appeared in the mainstream economy through classic works of Georgescu-Roegen and his concept of bioeconomics in the light of entropy law. The second law of thermodynamics (entropy law). It is the function of the state, determines the direction of spontaneous processes in an isolated system, is a measure of the degree of disorder of the system at the same time saying that in all the physical processes some energy is lost, it is assumed that the physical systems are not reversible. The economic mainstream applications of entropy law is the theory of intertemporal allocation of resources and environmental management [Georgescu-Roegen 1971]. Entropy of the economic system requires us to treat the economy as an open system, taken in conjunction with the system of ecological, political, and cultural, as well as to take into account the long time horizon and externalities [Manteuffel 2006].

The second factor that drives the development of bioeconomy from the theoretical perspective is the use of the renewable resources as a basis for most of production activities. In this respect the heterodox economic theory of the dynamic efficiency of the socio-economic systems serves as a principal approach. As argued by De Soto [2009] the traditional Pareto criteria of allocative efficiency, which have predominated in economics up to today, are tainted with a definite static character and therefore are inadequate to be applied as normative guidelines to the rich dynamics of real-life socio-economic conditions. The efficiency in the dynamic terms means to make such a choice between current and future consumption, which provides the expected increase in consumption per capita while maintaining the internal and external equilibrium of the economy in long term. Dynamic efficiency is the state of the economy, the essence of which, is the ratio of the level of savings and investments, which can increase consumption in the future [Abel et al. 1989, Szudy 2014].

The assumptions of the dynamic efficiency, which also complies with the concept of sustainability, were included into new and promising concept of the circular economy [*Towards the Circular*... 2013]. In the circular economy the material flows are of two types: biological nutrients, designed to reenter the biosphere safely; and technical nutrients, which are designed to circulate at high quality without entering the biosphere [*Towards a Circular*... 2014]. It encompasses more than the production and consumption of goods and services, including a shift from non-renewably resources to renewably and from fossil fuels to the use of renewable energy, and the role of diversity as a characteristic of resilient and productive systems [*Towards the Circular*... 2014].

From the above perspective can be concluded that the bioeconomy shall be considered as the dynamics of living resources in the socio-economic models. The bioeconomy determinates the threshold of socio-economics activity for which a biological system can be efficiently used without destroying the conditions for its regeneration and therefore its sustainability.

The scope of bioeconomy

The bioeconomy is on the one hand admittedly very ancient and traditional (bread baking, beer brewing, food conservation, char coal production), and on the other hand new and innovative (novel biomaterials, biopharmaceuticals, food, feed and cosmetic ingredients). The literature review of the definitions of the bioeconomy executed by Maciejczak and Hofreiter [2013] confirmed that there are scientific or theoretical doubts about the mainstream of the concept. Since the term was coined in 1997, the definition has evolved with shifting emphasis. All of definitions focus on renewable sources of production input. As far as output is concerned, the definitions mention food, health, chemical and energy sectors. The understanding of the concept differs also with regard to driving forces, mentioning sustainability, competitiveness and welfare as the most important.

The Bioeconomy Council of the German Government adopted a rather broad definition, stating that bioeconomy is the knowledge-based production and use of biological resources to provide products, processes and services in all economic sectors within the frame of a sustainable economic system [*Bioeconomy Innovation* 2010]. This definition of bioeconomy does not refer exclusively to biological resources acting as substitutes for other resources, but entails new products and processes as well. It can be completed by the approach undertaken by the Nordic Council of Ministers, which states that the aim of bioeconomy is a sustainable production and use of natural resources, applying the cross sectorial and systematic approach, with a basis in circular economy [Kiørboe et al. 2015].

These two above definitions describe in the broadest sense the scope of the bioeconomy, in which the focus is paid on clustering by different socio-economic processes both the traditional and innovative sectors of economy, that use renevable resources, and by applying knowledge and innovative technologies deliver products and services, through achieving objectives important from private and public point of view. This scope creates the basis for the analysis of the bioeconomy.

The perspectives of bioeconomy analysis

The current economic and political literature aiming to analyse the bioeconomy is rich of macroeconomic statistical data presenting the contribution of this cross-sector to the national or regional economy [Dubin 2007, Bartoszczuk 2014]. The literature review enabled to identify three main approaches to analyze the bioeconomy. All apply the system approach as a basis for analysis. Although they focus on the scope of the bioeconomy described above, differ in applying the perspectives of analysis. There could be distinguished: i) input-output approach, ii) value chain approach, and iii) market approach.

The input – output framework developed by Leeuwen et al. [2013] is focused on identification of the supply of biomass industries and linked with them demand industries delivering products and services produced from the biomass by using traditional or innovative technologies. This classical economic relation is considered as a responses for policies and market expectations, which provides drivers and constrains for development. The system generates also direct and indirect impacts for business, people and environment.

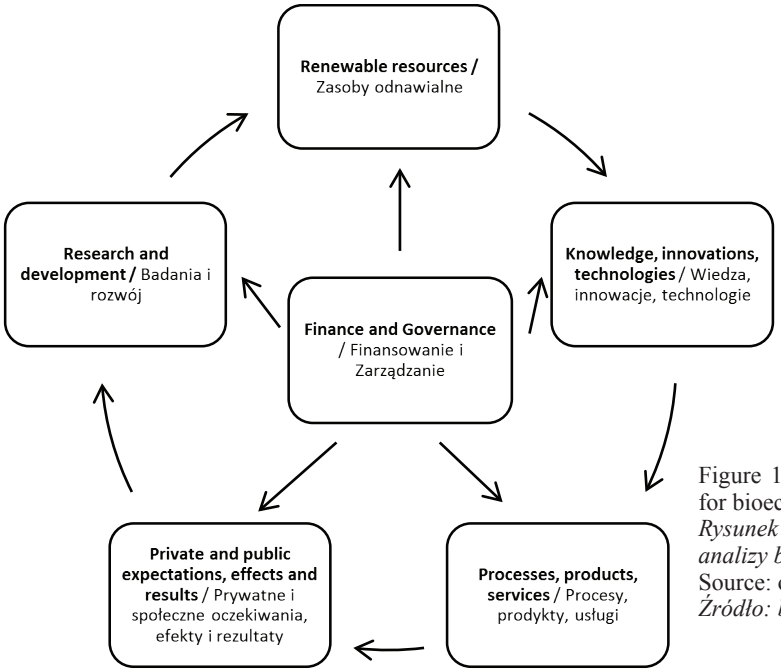

Figure 1. Conceptual framework for bioeconomy analysis
Rysunek 1. Ramy koncepcyjne dla analizy biogospodarki
Source: own research
Źródło: badania własne

The value chain framework assumed by German Bioeconomy Council [2010] was narrowed to the flow of product from raw material, which is biomass, through its processing and refinement, to production and marketing. These processes were assigned to the relevant sectors of the economy with primary focus on circular economy which utilizes new knowledge implemented through innovations.

The market framework proposed by Nita et al. [2013] presents the bioeconomy from three perspectives. A part from transformation of biomass into products and services by utilization of different technologies and knowledge, the system is presented also from the institutional perspective, where market, policies and science are influencing development. This development is shown also from the point of view of external effects, such as sustainability, growth and welfare.

The above described frameworks for bioeconomy analysis contain common perspectives of analysis. These perspectives could be summarized into one conceptual framework presented on the figure 1.

The conceptual framework for buioeconomy analysis describes the system in which renewable resources, which are primary resources from land and sea, as well as secondary resources which are wastes; in the process of adding value through application of knowledge, innovations and technologies; are transformed into processes, products and services expected from the private and public sectors. The development is ensured by the scientific endeavors, which are responses to the public and private needs. The processes that take place in this system are governed by the policies, regulations, but also market arrangements and market design.

This framework could be considered a response to the challenges of modern development programming model of quintuple helix for knowledge-based, innovative economies. The Quintuple Helix supports the formation of a win-win situation between ecology, knowledge and innovation, creating synergies between economy, society and environment [Carayannis et al. 2012]. The Quintuple Helix, thereby, visualizes the collective interaction and exchange of knowledge by means of the following five subsystems (i.e., helices): research and education system, economic system, natural environment, culture-based public system (also civil society), and the political system [Carayannis, Campbell 2010, 2011].

Conclusions

The bioeconomy is a dynamic complex phenomenon influenced by various global mega-trends. Understanding the roots of this complexity and identifying tools appropriate to its evaluation is hence prerequisite to effective policy formulation, governance and research. The bioeconomy is neither a new sector, nor a list of applications. It is defined by cross- sectoral principles rather than the sectoral borderlines of new or existing industries. These principles underline the assumptions of orthodox neoclassical and institutional economies, but also focus on the heterodox models of sustainability and systems dynamic efficiency. Answering the question stated in the title: how to analyze the bioeconomy one need to assume the complex system approach. The elements of the system can be regarded individually in the micro scale, also the interactions between the elements might be considered separately. There can be also macro perspective applied, in which the system is considered as a whole. Indisputably to analyze the bioeconomy from these and other perspectives will be a challenge, as its importance will grow in the years to come.

Bibliography

Abel A.B., Mankiw N.G., Summers L.H., Zeckhauser R.J. 1989: *Assessing Dynamic Efficiency: Theory and Evidence*, Review of Economic Studies, 56, 1-20.

Altmann M.P. 2011: *Contextual Development Economics A Holistic Approach to the Understanding of Eco-nomic Activity in Low-Income Countries*. Springer, London.

Bartoszczuk P. 2014: *Perspektywy rozwoju biogospodarki,* Zesz. Nauk. WSH, Zarządzanie, 2014(1), 357-364.

Bioeconomy Innovation. 2010: German Bioeconomy Council, Berlin.

Birch K., Levidow L., Papaioannou T. 2010: *Sustainable Capital? The Neoliberalization of Nature and Knowledge in the European "Knowledge-based Bio-economy*", Sustainability, 2, 2898-2918.

Birch K., Tyfield D. 2012: *Theorizing the Bioeconomy: Biovalue, Biocapital, Bioeconomics or . . . What?* Science, Technology, & Human Values, 38(3), 299-327.

Carayannis E.G., Campbell, D.F.J. 2010: *Triple Helix, Quadruple Helix and Quintuple Helix and How Do Knowledge, Innovation and the Environment Relate To Each Other?: A Proposed Framework for a Trans-disciplinary Analysis of Sustainable Development and Social Ecology,* International Journal of Social Ecology and Sustainable Development, 1(1), 41-69.

Carayannis E.G., Campbell, D.F.J. 2011: *Open innovation diplomacy and a 21st century fractal research, education and innovation (FREIE) ecosystem: building on the Quadruple and Quintuple Helix innovation concepts and the "Mode 3" knowledge production system,* Journal of the Knowledge Economy, 2(3), 327-372.

Carayannis E.S., Barth T.D., Campbell D.F.J. 2012: *The Quintuple Helix innovation model: global warming as a challenge and driver for innovation,* Journal of Innovation and Entrepreneurship, no. 1-2, 1-12.

Chan S. 2001: *Complex Adaptive Systems*, ESD 83, Research Seminar in Engineering Systems, October 31, 2001/November 6, 2001, Massachusetts Institute of Technology, Cambridge, MA.

Dubin A. (ed.). 2007: *Stan i kierunki rozwoju biogospodarki w Polsce*, Ministerstwo Nauki i Szkolnictwa Wyższego, Warszawa.

Foster J. 2004: *From Simplistic to Complex Systems in Economics*, Discussion Paper no. 335, School of Economics, The University of Queensland, St Lucia.

Georgescu-Roegen N. 1971: *The Entropy Law and the Economic Process*, Harvard University Press, London.

Global Bioeconomy Summit. 2015: [web page] http://gbs2015.com/the-summit, accessed 10.10.2015.

Gołębiewski J. 2015: *Zrównoważona biogospodarka – potencjał i czynniki rozwoju,* [in] A. Czyżewski, B. Klepacki (eds), *Problemy rozwoju rolnictwa i gospodarki żywnościowej w pierwszej dekadzie członkostwa Polski w UE,* Polskie Towarzystwo Ekonomiczne, Warszawa.

Harfouche A., Khoury S., Fabbrini F., Scarascia-Mugnozza J. 2014: *Forest biotechnology advances to support global bioeconomy*, Annals Of Silvicultural Research, 38(2), 42-50.

Innovating for Sustainable Growth: A Bioeconomy for Europe. 2012: European Commission, Brussels.

Kiørboe N., Sramkova H., Krarup M. 2015: *Moving towards a circular economy – successful Nordic business models,* Nordic Council of Ministers, Copenhagen.

Leeuwen van M., Meij van H., Smeets E., Tabeau E. (eds). 2013: *Overview of the Systems Analysis Framework for the EU Bioeconomy*, *Overview of WP1 in the EU FP 7 SAT-BBE project Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy*, LEI Wageningen UR, Wageningen.

Maciejczak M., Hofreiter K. 2013: *How to define bioeconomy*? Rocz. Nauk. SERiA, t. XV, z. 4, 244-246.

Manninen J., Nieminen-Sundell R., Belloni K. (eds). 2014: *People in the Bioeconomy 2044*, VTT Technical Research Centre of Finland, Kuopio.

Manteuffel H. 2006: *Wybrane aspekty zrównoważone go rozwoju obszarów wiejskich z punktu widzenia ekonomiki środowiska*. Zesz. Nauk. Akademii Rolniczej we Wrocławiu, nr 540, 303-310.

Miller J.H., Page S.E. 2007: *Complex Adaptive Systems: An Introduction to Computational Models of Social Life*. Princeton University Press.

National Bioeconomy Blueprint. 2012: The White House Washington DC.

Nita V., Benini L., Ciupagea C., Kavalov B. Pelletier N. 2013: *Bio-economy and sustainability: a potential contribution to the Bio-economy Observatory*. European Commission Joint Research Centre Institute for Envi-ronment and Sustainability, Ispra.

Nordic Bioeconomy. 2015: NORDEN, [online], http://www.norden.org/en/theme/nordic-bioeconomy, accessed 15.10.2015.

Pfau S.F., Hagens J.E., Dankbaar B., Smits A.J.M. 2014: *Visions of Sustainability in Bioeconomy Research*, Sustainability, 2014, 6. 1222-1249.

Ratajczak E. 2015: *Rolnictwo i leśnictwo w świetle koncepcji biogospodarki,* [in] A. Czyżewski, B. Klepacki (eds), *Problemy rozwoju rolnictwa i gospodarki żywnościowej w pierwszej dekadzie członkostwa Polski w UE,* Polskie Towarzystwo Ekonomiczne, Warszawa.

Renssen van S. 2014: *A bioeconomy to fight climate change*. Nature Climate Change 4, 951-953.

Szudy M. 2014: *Efektywność ekonomiczna w ujęciu dynamicznym a sprawność systemu gospodarczego.* Studia Ekonomiczne Uniwersytetu Ekonomicznego w Katowicach nr 176, p. 22-29.

Takács I., Nagy-Kovács E., Holló E., Marselek S. 2012: *Model for optimization of biomass utilization of energy production by energetic and economic requirements*. Review of Applied Socio-Economic Research, vol-ume 4, Issue 2/ 2012, p. 225.

Takács I., Takács-György K. 2013: *Arguments for the optimisation of using biomass for energy production*, Applied Studies in Agribusiness and Commerce, vol. 7, no. 2-3, 103-108.
The Bioeconomy to 2030. Designing a policy agenda. 2009: OECD, Paris.
Towards the Circular Economy: an economic and business rationale for an accelerated transition. 2013: Ellen Mac Arthur Foundation, [online], http://www.ellenmacarthurfoundation.org, accessed 05.10.2015.
Towards the Circular Economy: Accelerating the scale-up across global supply chains. 2014: World Economic Forum, Geneva.
Towards a Circular Economy. A Zero-Waste Program for Europe. 2014: European Commission, Brussels.
Zilberman D., Kim E., Kirschner S., Kaplan S., Reeves R. 2013: *Technology and the future bioeconomy*, Agricultural Economics, 44(2013), supplement, 95-102.

Streszczenie

Podjęto próbę określenia podstaw teoretycznych, zakresu oraz ram analitycznych dla koncepcji biogospodarki. Na podstawie przeglądu literatury przy wykorzystaniu założeń teorii systemów złożonych i teorii kontekstowej zaproponowano holistyczne podejście do postrzegania różnych wymiarów systemu biogospodarki i sposobów ich analizowania.

Correspondence address:
Mariusz Maciejczak, Ph.D.
Warsaw University of Life Sciences – SGGW
Faculty of Economic Sciences
Department of Economics and Management of Enterprises
Nowoursynowska Str. 166
02-787 Warsaw, Poland
phone: 48 (22) 593 42 35
e-mail: mariusz_maciejczak@sggw.pl