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BIOECONOMY AS A COMPLEX ADAPTIVE SYSTEM

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Abstract. The bioeconomy is recognized as a large system that binds together natural resources, technologies, markets, people and policies. It actively and continuously establishes links between industries, both old, that for a long time form a chain of added values and new, that previously had no connections, forming a symbiotic relationship where one industry utilizes the by-products of another. The paper describes this system in a dynamic approach, as a complex adaptive system. Complexity results from the inter-relationship, inter-action and inter-connectivity of elements within a system and between a system and its environment. Based on the empirical evidences from the European Union it is argued that bioeconomy as a platform networking several branches of economy could adapt to the changes that take place in the environment.

Key words: bioeconomy, complex adaptive systems, renewable resources, efficiency.

JEL code: L11, L50, Q01

Introduction

The concept of bioeconomy is recognized as not only a promise but also a solid and realistic foundation of achieving the sustainability needs worldwide. The idea is to cluster by different socio-economic processes both traditional and innovative sectors of economies that focus on the use of renewable resources, and by applying knowledge and innovative technologies, deliver products and services, through achieving objectives important from private and public point of view. The bioeconomy is also recognized as 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. As such bioeconomy is perceived very holistically in a wide systemic approach.

However, it is necessary to see this system not in a static way but apply more dynamic approach (Maciejczak M. and Hofreiter K., 2013). This is due to the dynamic and turbulent internal and external changes that practically prevent the achievement of Pareto optimum. Therefore, bioeconomy can be considered as a complex adaptive system. 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 (Levin R., 2000). Complex adaptive systems from economic perspective are characterized by Miller and Page (2007) 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. 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. It seems necessary to approach economic analysis of bioeconomy 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 (Golebiewska B., 2014).

The paper aims to analyze bioeconomy as a complex adaptive system. Based on the empirical evidences from the European Union countries it is argued that bioeconomy as a platform networking several branches of economy could adapt to the changes that take place in the environment. So far, the economic literature on bioeconomy issues in majority is applying the orthodox approaches from classical and neoclassical theories. The heterodox points of view are rarely undertaken. However, such approaches give the chances to analyse

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bioeconomy in a holistic way, assuming not only the dynamics of the concept but also its complexity, i.e. resulting not only from current state of the art but also from its path dependency. As several authors emphasize (Stack M. and Gartland M., 2013; Wolfre D.A. and Lucas M., 2005; Garrouste P. and Ioannides S., 2001), such approach enables to see the complex picture and observe the adaptation of economic systems, including the bioeconomy.

The presented research are based on the heterodox assumptions of deductive and descriptive reasoning, and the secondary data coming from the Bioeconomy Observatory of the European Commission, using the data management tool DataM2, which is capturing statistics related to bioeconomy.

Research results and discussion

In the social sciences, it is agreed that the complexity results from the inter-relationship, inter-action and inter-connectivity of elements within a system and between a system and its environment (Levin R., 2000; Mitchel M., 2011). As such, systems are able to adopt and become known as Complex Adaptive Systems (CAS). According to Miller and Page (2007) CAS are dynamic systems able to adapt in and evolve with a changing environment. As argued by Cham (2001), it is important to realize 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 system is 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 (Vanberg V.J., 2004). Axelrod (1997) argues that what distinguish a CAS from a pure multi-agent system (MAS) are: the focus on top-level properties and features like self-similarity, complexity, emergence and self-organization. A MAS is defined as a system composed of multiple interacting agents; where the agents as well as the system are adaptive and the system is self-similar. CAS is recognized as a complex, self-similar collectivity of interacting adaptive agents. Complex Adaptive Systems are characterised by a high degree of adaptive capacity, giving them resilience in the face of perturbation. Communication and cooperation take place on all levels, from the agent to the system level. Levin (2000) defines CAS systems in terms of three properties: diversity and individuality of components, localized interactions among these components and an autonomous process that uses outcomes of those interactions to select a subset of those components for replication or enhancement.

Day (1994) argues that when thinking of the economy as a complex system of elements the appropriate construct to understand it is the network. It is because the generated added value does not just come from the elements contained in the firm but from the connections that are forged between them. As networks evolve and produce more and better ranges of products using more productive processes, there is observed increasing value added. As shown by Vanberg (2004) firms are bundles of network connections, as are economies. Such networks cannot be fully connected or be maximally efficient, because an economic system is not a machine. Networks are constantly being created and destroyed, along with products and organizations (Jackson M. and Watts A., 2002; Rosser J., 1999).

From the point of view of economic theory, as stressed out by Metcalfe et al. (2006), complex systems theory is, essentially, a body of theory about connections, distinguishing it from conventional economic theory which is concerned with elements, supplemented by very strong assumptions about connections. Component structures in such systems evolve through a process of specialization and integration as well as the process of innovation diffusion. Foster (2004) distinguished four general properties of

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an economic complex adaptive system, which includes structure, its components, connections and evolution in the historical time domain.

Having in mind the above discriminants of the bioeconomy (Maciejczak M., 2015), and agreeing that as an economic system it has a network and complex structure as well as is influenced by the path dependency, one could distinguish its following properties:

1) agents – as every system the bioeconomy should be recognized as a set of economic agents performing different functions, not only devoted to supply and demand but also aimed to deliver knowledge or institutional framework;
2) connections – every agent in the bioeconomy system performs the role that results are transmitted by the links, also with feedback loops, established in the networks, which are subject to constant changes;
3) transformations – this characteristic is crucial for bioeconomy as much as crucial are renewable resources and knowledge, which both are used as basic sources for any bio-processes which create private and public value added;
4) openness – this approach enables to obliterate the boundaries between the agent – a firm and its environment, making them more permeable, and thanks to that, transfer innovations inward and outward; firms could become more innovative cooperating with partners by sharing risk and sharing reward;
5) evolution – the network of bioeconomy is subject to constant changes, which not only influence its development but are influenced by all historical changes.

Figure 1 presents the conceptual model of bioeconomy as a complex system. Such system is built of agents, which are connected. In such system products and services are generated from application of knowledge and innovative technologies into production processes which base on renewable sources of biomass. By application of non-linear models of progress development and innovation diffusion as well as being pulled by the market, the bioeconomy system can generate products and services important from private and public point of view. Both, private and public institutions finance and govern its functioning and growth.

Is, however, the bioeconomy not only complex but also adaptive? To answer this question two synergetic arguments can be used. First is describing the evolution of the bioeconomy concept. The second is showing how path dependency resulted in the primary production of energy from renewable sources.

In one of the first policy agendas of the bioeconomy, namely the Cologne Paper (European Commission, 2007) bioeconomy is recognized as the production of renewable biological resources and their conversion into food, feed, bio - based products and bioenergy. Here, is provided very narrow approach which is encompassing the classical production function. In 2012, the European Commission stressed out that production paradigms of bioeconomy should rely on biological processes and, as with natural ecosystems, use natural inputs, expend minimum amounts of energy and do not produce waste as all materials discarded by one process are inputs for another process and are re-used in the ecosystem (European Commission, 2012). In the evolution of bioeconomy concept in Europe could be observed the focus not only on production but also on energy savings and circularity of renewable resources, i.e. wastes. In 2015 the Council of Nordic States – Norden, pointed out that bioeconomy is a sustainable production and use of natural resources, with a cross-sectorial and systematic approach, with a basis in circular economy (The Council of Nordic States, 2015). In this definition, being an example of the broadest approach, are emphasized the elements of governance of production and circularity of the system.

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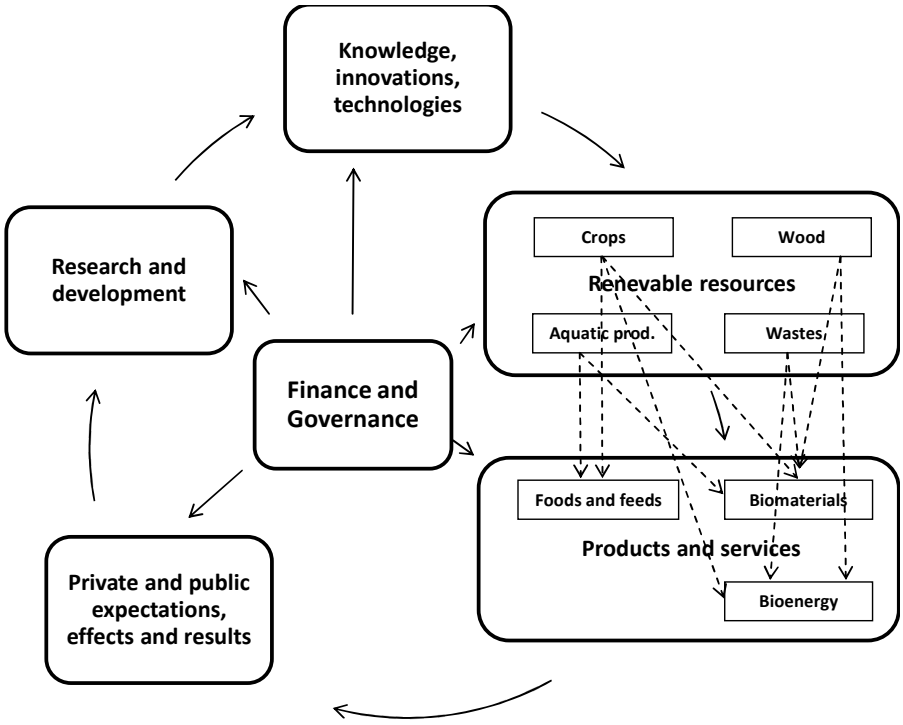
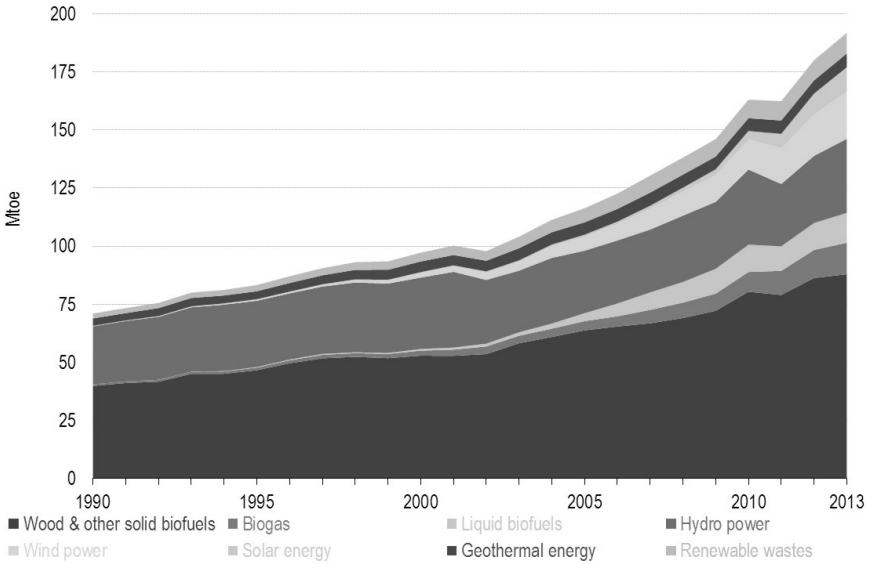


Source: author's construction

Fig. 1. **The conceptual model of bioeconomy as a complex system**



Source: author's construction based on Eurostat data

Fig. 2. **Primary production of energy from renewable sources, EU-28, 1990-2013**

Figure 2 presents the primary production of energy from renewable sources in the European Union 28 Member States, in the years 1990-2013. As the concept of bioeconomy evolved into use not only of primary sources of biomass, such as wood or agricultural crops and residues but also biomass from renewable wastes, such products were increasingly gaining higher shares in the energy production. Similar, path dependency situation can be observed with regard to liquid biofuels or hydro power.

Conclusions and recommendations

1) This paper aimed to make an attempt to present and analyse bioeconomy as a complex

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adaptive system. The performed analysis allow for the following conclusions:

2) The classical perspectives of perceiving and, as a consequence, analysing economy are changing from market approach of static equilibriums into industrial organizations of dynamic networks.

3) Bioeconomy as a concept gaining more and more attention of society, business, politics and academy could and should also be analysed from the perspective of more heterodox approaches, including industrial organization.

4) Bioeconomy can be presented as the complex adaptive system. The system, which using path dependency and connections between agents participating in evolving networks, is able not only to produce high added value but also adapt to the changing environment.

5) It is advisable that further research on bioeconomy as complex adaptive system should be undertaken, in order to present all spectrum of issues related to its key properties distinguished in this paper and beyond.

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