Scientific Journal Warsaw University of Life Sciences – SGGW
Problems of World Agriculture volume 15 (XXX), number 4, 2015: 137–146

Mariusz Maciejczak[1]
Faculty of Economic Sciences,
Warsaw University of Life Sciences – SGGW

What are Production Determinants of Bioeconomy?

Abstract. The concept of bioeconomy focuses on clustering different socio-economic processes of both traditional and innovative sectors of economy that focus on the use of renewable resources, and by applying knowledge and innovative technologies, and delivering products and services that are important from private and public points of view. Such an approach requires utilization of resources that differ from classical economic classification of production factors. The paper argues that instead of land, labor, capital and entrepreneurship, from the bioeconomy point of view it is more important to look at: renewable resources such as biomass sources, investments in research and development activities and people engaged in such activities as well as innovations, which could be considered as production determinants. Based on the latest Eurostat data for the year 2011, the paper presents the state of these determinants in the European Union's main bioeconomy sectors.

Key words: bioeconomy, production determinants, biomass, investments in research and development, research personnel, innovations, European Union

Introduction

The bioeconomy is widely recognized as a concept whose core function is the use of natural resources by applying the cross sectoral and innovative approach, with a basis in circular economy. 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 [European Commission 2014]. It encompasses more than the production and consumption of goods and services, including a shift from non-renewably resources to renewable, and from fossil fuels to the use of renewable energy, and the role of diversity as a characteristic of resilient and productive systems [World Economic Forum, 2014]. Several authors [Takács and Takács-György 2013, Pfau et al. 2014, Gołębiewski 2013] point out that wider application of circularity and use of renewable resources is a basic contribution of bioeconomy to development based on sustainable principles. In this context, bioeconomy is perceived as a concept that could contribute to more sustainable growth in various ways, achieving a positive environmental and social impact, while ensuring economic growth through innovative products and the preservation of traditional sectors, such as food production. As such, bioeconomy is perceived very holistically in a wide systemic approach [Maciejczak 2015b].

Taking into account such systemic a approach, one needs to emphasize that in the bioeconomy concept 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. Efficiency in dynamic terms means to make such a choice between current and future consumption, which provides the expected increase in

[1] PhD, e-mail: mariusz_maciejczak@sggw.pl

consumption per capita while maintaining the internal and external equilibrium of the economy in the long term [De Soto 2004]. The essence of dynamic efficiency, is the ratio of the level of savings and investments, which can increase consumption in the future [Abel et al. 1989; Szudy 2014].

However in order to ensure consumption, savings and investments, the bioeconomy sector, under dynamic and constant changes, needs to produce added value from raw materials, which in turn will serve as a basis for income and profits. Classical and neoclassical economic theories distinguish between three basic factors of production: land, labor and capital. Some authors on the basic factors of production include also entrepreneurship and knowledge. It is argued in this paper that while these factors have been much discussed and extended at different points in economic evolution, in any of the advanced economies of the world today, especially in such emerging concepts as bioeconomy, they are vastly antiquated. There is a need to focus on the basic economic assumptions, such as the production functions, and to fill in the gaps in current understanding of the bioeconomy, in order to describe the main factors that drive its development.

Objectives and methods

The paper aims to make an attempt to name the new production factors under the bioeconomy concept, with the prerequisites of heterodox economics, and describe them using the example of the Member States of the European Union. The presented research is based on the heterodox assumptions of deductive and descriptive reasoning, and on secondary data coming from the Bioeconomy Observatory of the European Commission, which captures statistics related to bioeconomy. In order to present a comprehensive picture of the situation in the analyzed region, the time frame was limited to the year 2011.

There is no single heterodox economic theory, but there are many different programs and theories in existence. What they all share, however, is a rejection of the neoclassical orthodoxy as representing the appropriate tool for understanding the workings of economic and social life today [Lee 2011, Mearman 2011]. For example, the concept of market equilibrium has been criticized by Austrians, post-Keynesians and others, who object to applications of microeconomic theory to real-world markets, when such markets are not usefully approximated by microeconomic models [Lawson 2005]. However, under the umbrella of the heterodox economics there are several provisional elements, such as critical realism, non-equilibrium, institutions and agency, the socially embedded economy, as well as circular and cumulative change, which have emerged from a synthesis of arguments, and are associated to social processes in complex systems.

New production determinants used for bioeconomy

In mainstream economic theory there are assumed three main factors of production: land, labor and capital. Land as a factor of production is understood very broadly. This concept includes minerals, underground and surface waters, territory, fauna, flora and atmosphere. Labor, and more precisely – work – is understood as a physical person's ability to perform certain actions, together with his/her skills and motivations. Today the identification of working with human capital is spreading. Capital as a factor of production is understood in substantive terms (rather than financial). It consists of machinery and equipment for the production of other goods. Some authors on the basic factors of production include entrepreneurship and knowledge. Entrepreneurship is sometimes included in the labor factor [Samuelson and Nordhause 2009; Perloff 2008].

The above classification of factors has come under criticism by many economists [Malkiel 2003, Grossman and Stiglitz 1980, Harcourt 2010]. Firstly, from many of critical assumptions one can distinguish problems with substitution. Each unit of a factor can be distinguished from other units of that factor, but one factor can be substituted for some other factor. For instance, land can be used intensively by employing more labor or more capital in the form of fertilizers, better seeds and superior techniques. By so doing, one can substitute labor or capital for land. Similarly, labor can be substituted for capital, and capital for labor in a factor. The degree of substitution of one factor for another will, however, depend on the most efficient method of production to be used relative to the cost of the factor to be substituted. Secondly, another problem arises as a critique because land, labor and capital often get intermixed into one another and it is difficult to specify the contribution of each separately. For instance, when land is cleared, canals are dug and fences are erected, the productivity of land increases. But all these improvements on land are possible by making capital investments and through labor. In such a situation, it is not possible to specify the contribution of land, labor and capital in increasing productivity. Finally, there are arguments against too wide a meaning of factors of production. It is argued that it is more convenient to consider only the land which can be bought and sold as a factor of production, rather than such elements as sunshine, climate, etc. which do not enter directly into costs. Similarly, it is not accurate to group together the services of an unskilled worker with that of an engineer, or of an engine driver with that of a serviceman in the railways. Therefore as shown by [Xu et al. 2009, Xu 2009] who proposed an alternative theory of six forces of essential factors of production, several authors find it more accurate to lump together all homogeneous units, whether hectares of land, workers, or capital goods, and to consider each group as a separate factor of production. This method gives a large number of factors of production and each group is regarded as a separate factor.

Thus, in the large body of economic literature one can identify more than just classical production factors. Due to technical and technological advancements some name technology as a new production factor [Brynjolfsson and Hitt 1994]. They argue that, thanks to technology, firms can capture high growth under dynamic changes in the environment. There is a big group of economics with its classical frontman Schumpeter [1964] that consider innovations as a new production factor. These authors [i.e. Bowman and Zilberman 2013, Takács-György 2014, Smolny 2000] focus on marginal utility of innovations as a source of growth. Other scientists pay attention to institutions as a fundamental cause of long-run growth [Engerman and Solkoloff 1995; Chavas and Kim 2010, Maciejczak 2015a]. One could argue, if the above approaches and the variables indicated are new factors, they could be considered, especially from an epistemological point of view [see Mises 1981], really as new production factors. Having in mind the epistemological understanding of production factor as a durable input employed in production activities, once could name new variables influencing and employed in the production processes as determinants. Such understanding was used by Binswanger and Rozenzweig [1986] as well as Mundlak et al. [1997]. The determinant is a factor which decisively affects the nature or outcome of something and a thing that decides whether or how something happens [Oxford Advanced Learner's Dictionary 2011].

There is, however, no particular focus on the bioeconomy as a special subject of research from the production factor point of view, so far. This is not due to the novelty of the idea, but rather from its complexity. As argued by Maciejczak [2015b], bioeconomy brings together processes that have so 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 consumer expectations. It actively establishes links between industries, both old (which for a long time formed a chain of added values) and new (which previously had no connections) within a new, symbiotic relationship where one industry utilizes the by-products of another. Thus it forms a new network-oriented platform. The bioeconomy creates a new dimension within existing elements of the socio-economic system, in which large-scale progress in various forms, especially biological and technical, is created, as well as successfully introducing product and process innovations.

Having in mind the common definition of bioeconomy, which states that it 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 [German Bioeconomy Council 2010], it needs to be stated that the sources of biomass are primary production determinants of the bioeconomy. The biological resources exclusively are acting as substitutes for other (fossil) resources. Two other production determinants are also included in the above definition. They are related to knowledge, and focus on the investment in research and development (R&D) in the bioeconomy system as well as people employed in it, who have obtained sufficient knowledge to explore, commercialize and develop products and processes important from the point of view of firms and society. Finally, the fourth determinant is connected to the organization of the system. It is the institutional arrangements that enable implementation of solutions that ensure competitiveness under dynamic changes. The four production determinants of bioeconomy are presented in Figure 1. These factors are characterized by the homogeneity and the orientation on generating the highest marginal utility and added value not only from the firm but also from the network.

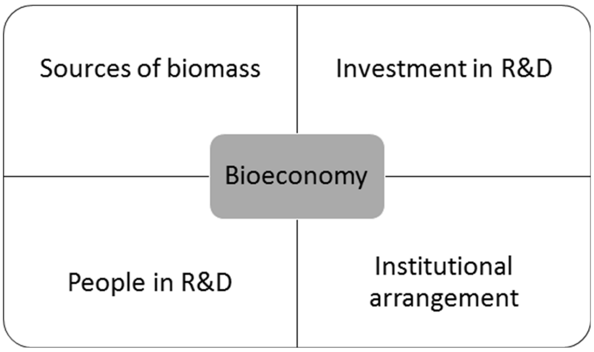

Fig 1. Production determinants of bioeconomy

Source: author’s own elaboration.

Bioeconomy's production determinants in the European Union

The basic bioeconomy production determinants are sources of biomass. Biomass is organic, non-fossil material of biological origin that can be used as biogenic feedstock in food supply, other products, and for generating energy in the form of heat or electricity. The sources of biomass are crops (excluding fodder crops): cereals, nuts, vegetables, fruits, fibres, etc.), crop residues (fodder crops and grazed biomass), animals (fishing, hunting, cultivated land/aquatic animals, animal products, etc.), wood as well as wastes (household, industrial, communal, etc.).

Table 1. The production of biomass resources in the European Union Member States in 2011

Member State	Resurces of biomass			
	Agriculture [in 1000 t of dry matter of biomass]	Aquaculture [in 1000 t of living weight]	Wood [in 1000 cubic meters]	Waste [in 1000 t]
Austria	8,5	1,3	18696	179,1
Belgium	10	22,3	5128	1120,5
Bulgaria	12	16,1	6205	903,2
Croatia	7	87,3	5258	75,1
Cyprus	2	5,8	8	150,5
Czech Republic	14	2,4	15381	196,1
Denmark	16	793,4	2583	201,1
Estonia	20	78,4	7116	77,1
Finland	6	136,1	50767	3157,9
France	110	680,5	55041	1616,5
Germany	80	270,6	56142	648,9
Greece	7	174,1	1196	9,9
Hungary	15	0,1	6232	430,5
Ireland	5	250,5	2635	101,2
Italy	19	376,7	7744	310,9
Latvia	6	156,7	12833	2,8
Lithuania	7	140,4	7004	455,9
Luxembourg	1	0,2	261	1,2
Malta	1	6,1	1	2,6
Poland	51	201,7	37180	1952,8
Portugal	3	223,1	10961	83,4
Romania	23	8,9	14359	18352
Slovakia	6	1	9213	549,4
Slovenia	2	2,1	3388	164,8
Spain	27	241,2	15428	5496,5
Sweden	8	195,6	71900	273,1
The Netherlands	8	408,7	982	4946,5
United Kingdom	31	793,6	10020	748,4

Source: author's own elaboration based on DataM web, provided by the European Commission/ Joint Research Centre, www.datamweb.com. Data accessed on 21/12/2015.

Table 1 presents the capacity of biomass resources in the European Union (EU) Member States (MS). There are distinguished agricultural resources (both plant and livestock), aquaculture resources (both maritime and inland), wood and waste resources. In 2011, three MS: France, Poland and United Kingdom produced 38% of agricultural biomass. Accordingly over 50% of total production of aquaculture biomass was produced by four MS: United Kingdom, Denmark, France and The Netherlands. Similarly 53% of total production of wood biomass in the EU comes from four countries, namely: Sweden, Germany, France and Finland. The biggest producers of biomass from waste in the EU are Romania, Spain, The Netherlands and Finland, which together account for 75,7% of total biomass production from wastes. The above date shows high polarization of resources of biomass production among the EU's MS.

Table 2. Private enterprise expenditures on R&D in 2011 [mln Euro]

Member State	Direct bioeconomy sector				
	Agriculture	Food and beverages	Leather	Paper and pulp	Wood
Austria	2	28,7	2,6	23,6	15,27
Belgium	25,8	121,6	7,7	10,4	5,67
Bulgaria	0,4	0,2	*	*	*
Croatia	0,1	9,1	*	*	0,2
Cyprus	*	0,6	*	*	*
Czech Rep.	4,6	13,4	0,7	1,3	1,7
Denmark	7	68,4	*	1,7	1,44
Estonia	0,1	1,4	*	*	*
Finland	4,9	*	*	75,9	9,6
France	150,4	*	6,1	40,9	14,39
Germany	126,1	*	5,5	61,3	22,6
Greece	1,5	*	*	*	*
Hungary	14,3	15,5	*	2	0,9
Ireland	2,1	*	*	*	8,09
Italy	3,3	150,3	120,7	48,3	13,6
Latvia	*	*	*	*	*
Lithuania	*	2	0,1	0,2	*
Luxembourg	*	1,1	*	*	*
Malta	0,6	0,6	*	*	*
Poland	6,6	*	*	3,6	*
Portugal	2,9	41,4	5,2	13,2	9,52
Romania	1,3	1,5	*	*	*
Slovakia	1,5	1,2	*	*	*
Slovenia	0,4	3,6	1	1,9	1,79
Spain	53,3	*	11,8	24,9	12,66
Sweden	22,3	*	*	100,7	*
The Netherlands	172,3	388,5	0,6	8,8	1,95
United Kingdom	14,3	244,7	1,5	10,1	1,61

Source: author's own elaboration based on DataM web, provided by the European Commission/ Joint Research Centre, www.datamweb.com. Data accessed on 21/12/2015. * - no data available.

Similar polarization is observed as another factor is considered, namely: private (firms) investment in research and development. According to available data, the leading MS are The Netherlands, United Kingdom and Italy (Table 2). Analyzing particular bioeconomy industries 45,1% of investments are made in the food sector, 25,5 in the agricultural sector, 17,7% in paper and pulp sectors, 6,7% in the leather sector, and 5% in the wood sector.

Table 3. R&D personnel and researchers in business enterprise sector by economic activity in 2011 [in total working units]

Member State	Direct bioeconomy sector				
	Agriculture	Food and beverages	Leather	Paper and pulp	Wood
Austria	22	312	35	156	137
Belgium	293	1178	42	104	90
Bulgaria	65	21	*	*	*
Croatia	4	173	*	*	7
Cyprus	*	14	*	*	*
Czech Rep.	186	192	27	19	7
Denmark	49	642	*	21	18
Estonia	3	40	*	*	*
Finland	37	*	*	509	73
France	1414	*	84	468	208
Germany	1189	*	66	581	173
Greece	50	*	*	*	*
Hungary	475	427	*	2,7	41
Ireland	20	551	*	*	*
Italy	79	1978	1572	570	241
Latvia	5	9	*	8	*
Lithuania	4	81	7	9	3
Luxembourg	*	21	*	*	*
Malta	20	28	*	*	*
Poland	258	*	*	51	76
Portugal	46	543	117	108	109
Romania	143	*	37	*	*
Slovakia	65	35	*	*	*
Slovenia	4	85	17	16	25
Spain	882	*	170	266	168
Sweden	*	*	*	*	11
The Netherlands	2219	3130	9	130	40
United Kingdom	196	3021	40	107	29

Source: own elaboration based DataM web, provided by the European Commission / Joint Research Centre, www.datamweb.com. Data accessed on 21/12/2015. * - no data available.

Analyzing total R&D personnel and researchers in bioeconomy sectors of the EU, according to available data, without any surprise, similar to investments, the leading MS are The Netherlands, United Kingdom and Italy (Table 3). An also similar structure for investment is observed as the engagements in the particular sectors are concerned. 46,2% of R&D staff is working in the food sector, 28,6% in the agricultural sector, 11,6% in paper and pulp sectors, 8,2% in the leather sector, and 5,4% in the wood sector.

Table 4. Patent applications to the European Patent Office (EPO) by sector of economic activity in 2011

Member State	Direct bioeconomy sector			
	Agriculture	Food and beverages	Paper and pulp	Wood
Austria	21	17	11	2
Belgium	19	19	8	1
Bulgaria	0	0	0	0
Croatia	0	0	0	0
Cyprus	0	0	0	0
Czech Rep.	3	3	1	0
Denmark	14	13	6	1
Estonia	0	0	0	0
Finland	10	9	7	1
France	58	68	37	7
Germany	252	225	130	18
Greece	2	3	0	0
Hungary	1	2	1	0
Ireland	5	4	1	0
Italy	43	63	30	6
Latvia	0	1	0	0
Lithuania	0	0	0	0
Luxembourg	0	1	1	0
Malta	0	0	0	0
Poland	1	4	3	1
Portugal	1	1	1	0
Romania	1	1	1	0
Slovakia	0	0	0	0
Slovenia	0	2	0	0
Spain	16	25	7	1
Sweden	9	12	8	1
The Netherlands	57	38	15	2
United Kingdom	26	48	21	3

Source: author's own elaboration based on DataM web, provided by the European Commission/ Joint Research Centre, www.datamweb.com. Data accessed on 21/12/2015.

The fourth new bioeconomy determinant of production is institutional arrangement. It is difficult to illustrate this by exact data. However for the purposes of this paper it was assumed that the quality of institutional arrangement in the MS of the EU can be presented as patent applications to the European Patent Office (Table 4). Patents are used as a quantified factor of arrangements that enable development and utilization of knowledge. The highest number of patents: 625 were filled in Germany, in each of three other countries: United Kingdom, The Netherlands and France there were filed more than 100 patent applications. The highest share of patent applications was filled from the food sector: 39,1% and agricultural sector: 37,8%. Accordingly, from the paper sector was filled 20,2% of applications and from the wood sector only 3%.

Conclusions

The bioeconomy as a network system has a unique characteristic that requires special theoretical, methodological and analytical frameworks in order to capture its diversity, complexity, adaptability and dynamics. Its complex structure, processes and objectives should be analyzed from the economic perspectives not as heterogeneous, but rather as a homogenous factors. Such an approach, close to other heterodox economic theories, can be applied once production functions of bioeconomy are concerned. The analysis executed in this paper led to the replacement of classical production factors by new determinants applicable to bioeconomy conditions. These new production determinants of bioeconomy are: sources of biomass, investment in R&D, competent people engaged in R&D as well as institutional arrangements of the sector. The analysis of these determinants in the Member States of the European Union show that among 28 countries there is large polarization in the engagement of these factors. Accordingly, the main sectors of bioeconomy that use the production factors are agriculture and food. There is big potential for the wood sector and yet undiscovered chances for waste resources.

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, p. 1-20.

Biswanger H., Rosenzweig M.R. [1986] Behavioral and Material Determinants of Production Relations in Agriculture. The Journal of Development Studies 22, pp.503-539.

Bowman, M. S., and Zilberman D. [2013]: Economic factors affecting diversified farming systems. *Ecology and Society* 18(1): 33.

Brynjolfsson E. and Hitt L. [1994]: Technolgy as a Factor of Production. *Sloan Working Paper* 3714, MIT Sloan School, Cambridge, Massachusetts.

Chavas, J. P., and K. Kim. [2010]: Economies of diversification: A generalization and decomposition of economies of scope. *International Journal of Production Economics* 126:229-235.

De Soto J.H. [2008]: The Theory of Dynamic Efficiency, 1st Edition. Routledge. London.

Engerman S.L. and Sokoloff K.L. [2003]: Institutional and non-institutional Explains of Economic Differences. NBER WorkingPaper no. 9989.

European Comission [2015]: Biomass estimates - database DataM, www. www.datamweb.com. Data accessed on 21/12/2015.

European Commission [2014]: Towards a Circular Economy. A Zero-Waste Program for Europe. Com (398). Brussels.

German Bioeconomy Council [2010]: Bioeconomy Innovation. Berlin.

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

Grossman S. J. and Stiglitz J.E. [1980]: On the Impossibility of Informationally Effcient Markets. *American Economic Review,*70:3, pp. 393–408.

Harcourt G. [2010]. The crisis in mainstream economics. Real-world Economics Review, issue no. 53., Cambridge University, UK.

Lawson T. [2005]: The nature of heterodox economics" Cambridge Journal of Economics 30 (4): 483–505.

Lee F. [2011]: A History of Heterodox Economics: Challenging Mainstream Views in the 21st Century. Routledge.

Maciejczak M. [2015a]: Will the institution of coexistence be re-defined by TTIP? Contributed paper prepared for presentation at the Seventh International Conference on Coexistence between Genetically Modified (GM) and non-GM based Agricultural Supply Chains(GMCC-15) Amsterdam, The Netherlands, November 17-20.

Maciejczak M. [2015b]: How to analyze bioeconomy. Annals of Polish Association of Agricultural Economists and Agribusiness, vol. XVI, issue 6.

Malkiel B. [2003] The Efficient Market Hypothesis and Its Critics. Journal of Economic Perspectives, Volume 17, Number 1.

Mearman A. [2011]: Who Do Heterodox Economists Think They Are? American Journal of Economics and Sociology, 70(2): 480–510.

Mises von L. [1981] Epistemological Problems of Economics. New York University Press.

Mundlak Y., Larson D., Butzer R. [1997]. The determinants of agricultural production. Policy Research Working Paper no. 1827. World Bank.

Oxford Advanced Learner's Dictionary of Current English. Oxford University Press.

Perloff J. M. [2008]: Microeconomics. 5th ed. Addison Wesley.

Pfau S.F., Hagens J.E., Dankbaar B., Smits A.J.M. [2014]: Visions of Sustainability in Bioeconomy Research. Sustainability no. 6, p. 1222-1249.

Samuelson P., Nordhaus W. [2009]: Economics 19th Edition. McGraw-Hill Education. London.

Schumpeter J.A. [1947]: Theoretical Problems of Economics. Journal of Economic History, Vol 7/1947.

Smolny W. [2000]: Endogenous Innovations and Knowledge Spillovers. A Theoretical and Empirical Analysis. The ZEW Economic Studies. Springer.

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., Takács-György K. [2013]: Arguments for the optimisation of using biomass for energy production. Applied Studies in Agribusiness and Commerce, Volume 07, Number 2-3.

Takács-György K. [2014] Imitation vs. Innovation in the SME sector. Annals of Polish Association of Agricultural Economists and Agribusiness, vol. XV, issue 2.

World Economic Forum [2014]: Towards the Circular Economy: Accelerating the scale-up across global supply chains. Geneva.

Xu, B., Chaudhry, S. S. and Li, Y. [2009]: Factors of production: Historical theories and new developments. Syst. Res., 26: 219–224.

Xu, S. [2009]: Theory of six forces of essential factors of production. Syst. Res., 26: 211–218.