

BIOECONOMICS AS AN INTERDISCIPLINARY SCIENCE

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Abstract. The aim of this paper is to identify and elucidate the bioeconomics, which traces the links among biology and economy, as a relatively new field of economics and political economy. To make a clear distinction between bioeconomics and bioeconomy, the paper presents a set of definitions of both categories and explains the reasoning behind them. This research is of theoretical nature and is based on extensive review of the scientific literature dealing with the relationship of biology with social sciences, including theories of leading contributors to economic thought. Such phenomena as evolution, cooperation, competition over scarce resources, selection, work division, signalling, territorialism and migration are the common to the economy of nature and the human economy. The study finds out that the conceptual and methodological trade between economic discourse and biological discourse goes back, at least, to the 18th century but many parallels between economic and social behaviour of humans and biology were observed and studied much earlier. Contemporary bioeconomists argue that economics and biology can mutually enrich each other, emphasize on what biology can be taught from economics and how economics can accommodate insights from biology.

Key words: bioeconomics, bioeconomy, economics, history of economic thought.

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Introduction

Many problems and challenges in today's world require economic sciences to work effectively with other disciplines. As Popper puts it, "*We are not students of some subject matter but students of problems. And problems may cut right across the borders of any subject matter or discipline*" (Popper, 1963).

Economics is a social science, born out of philosophy and history but drawing of the insights of sociology, geography, psychology, the study of law, government and politics, and, to a rising extent, the natural sciences, including biological and environmental sciences that offer very much to economic scientists. Obviously, any well-educated economist knows that the beginning of economics (political economy) as a modern academic discipline has been marked by the publishing of Adam Smith's "*An Inquiry into the Nature and Causes of the Wealth of Nations*" in 1776. Smith and other classics, however, did not build their theories in a vacuum but were influenced by the precursors of economics and the natural scientists as well.

The focus in this paper is, generally, on the interactions between economics and biology. Its purpose is to present a relatively new branch of

economics and political economy called bioeconomics. As terms bioeconomics and bioeconomy are often used interchangeably, the paper task is to provide precise definitions and interpretations of both in order to demonstrate the distinction between them. The research is theoretically descriptive in nature and is rooted in extensive examination of literature on the relationship of biology sciences with social sciences, including theories of leading contributors of economic thought. As it will be shown in the next section of the paper, biology and economics have interacted for centuries, and many scholars studying economic phenomena and processes were referring to biology.

The term "*bioeconomics*" (bionomics, economic biology, biological economy and environmental economics as antecedents), which comprises two words: biology and economics, suggests that bioeconomics can be viewed as interdisciplinary discipline or research which closely ties economics to natural sciences (e.g. evolutionary biology). Robert Axelrod (2008) describes interdisciplinary research as a mode of research that integrates information, techniques, perspectives, concepts and/or theory from two or more disciplines or bodies of organized or

specialized knowledge. According to National Academies of Science (2004), its purpose is to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or field of research.

Research results and discussion

1. What is the bioeconomics?

As it was said before, bioeconomics is a framework that brings together two scientific disciplines: economics and biology. The term "bioeconomics" was coined by British biologist Hermann Reinheimer in his work "Evolution by Co-operation: A Study in Bioeconomics" published in 1913. Definitions of bioeconomics

proposed by him and other authors in various research publications are provided in Table 1.

Bioeconomists maintain that the applicability of standard economic theory's constrained maximization (optimisation) framework is not confined to human behaviour and that this optimisation framework is suitable to describe behaviour of all evolved creatures throughout the animal kingdom (Vromen, 2007). They also insist that human socio-economic organization involves and depends on the human organism in its natural environment, and study how metaphors from biology can be used in economics and vice versa.

Table 1

Selected definitions of bioeconomics

| Authors | Definitions |
|---------------------------|---|
| Reinheimer, 1913 | The study of how organisms of all kinds earn their living in "nature's economy" with particular emphasis on co-operative interactions and the progressive elaboration of the division of labour. |
| Georgescu-Roegen, 1977 | The term bioeconomics is intended to make us bear in mind continuously the biological origin of the economic process and thus spotlight the problem of mankind's existence with a limited store of accessible resources unevenly located and unequally appropriated. |
| Tullock, 1979 | The application of standard economic theory, and its behavioural assumption that individuals are constrained maximizers, in studying biological phenomena. |
| Magee, 1993 | Bioeconomics is a one-factor theory based on hierarchy, which can explain both economics and politics. In bioeconomics, the strong dominate the weak in economic, political and social life. |
| Landa and Ghiselin, 1999 | Bioeconomics aims at the integration or "consilience" of two disciplines, economics and biology for the purpose of enriching both disciplines by substantially enlarging the theoretical and empirical bases which ultimately contribute to building of new hypotheses, theorems, theories and paradigms. |
| Witt, 1999 | The research paradigm combining two independent, though in many respects related, scientific disciplines: economics and biology. |
| Ghiselin, 2005 | The field that uses an expanded microeconomics to examine animal behaviour, human behaviour, and animal and human social institutions. |
| Vromen, 2007 | Bioeconomics concentrates on the significance of past evolutionary processes for studying current behaviour. |
| Gallagher, 2008 | Bioeconomics refers to political economy's concentration on the interconnections among populations, the food supply, modes of production and exchange, and their impact on life forms generally. |
| Khalil and Marciano, 2010 | The principle of rationality applied to non-human organisms. |
| Current authors | Transfer of biological approach to the human economy and economic approach to the behaviour of non-human organisms. |

Source: authors' construction based on the review of literature

As literature review shows, comparison between economy and biology is made either by relating economic firms to individual plants or animals, or economic industries to species (Hirshleifer, 1977; Landa and Ghiselin, 1999), or else entire species to firms (Crocker and Tschirhart, 1992). Table 2 presents some

similarities between ideas and approaches applied by economists and biologists. Evolution, selection, cooperation, competition over scarce resources, behaviour optimisation, labour division, signalling, territorialism and migration are examples of the issues common to the economy of nature and the human economy.

Table 2

Analogies between economics and biology

| Economics | Biology |
|--|--|
| The tragedy of the commons Concepts: externalities, cheating, punishment, common pool resources, public goods, free riding. Solutions: establishing private property, taxes, tradable permits, quotas, social pressure, punishment, government regulation | The tragedy of the commons Concepts: cheating, punishment, collapsing tragedy, component tragedy, social goods Solutions: kin (group) selection, punishment, "parliament of the genes" |
| Rational choice theory, consumer utility maximization, profit maximizing firm | Optimal foraging behaviour of animals, fitness and net energy maximization |
| Scarcity of resources, "no free lunch" principle, trade off, alternative costs | The law of compensation or balanced growth (to spend on one side, nature is forced to economise on the other side) |
| Kin-related behaviour and family life, optimal investments, optimal growth, dynamic optimization | Optimal life history strategies, reproduction value, dynamic optimization |
| Market signals, signalling costs, market screening, asymmetry of information | Handicap principle, animal's signalling and communication |
| Cooperation, the logic of collective action, human altruism and reciprocity | Animal collective behaviour, biological altruism |
| Game theory and interaction of strategically behaving actors | Evolutionary game theory: animals, trees, genes |

Source: authors' construction based on the review of literature

The tragedy of the commons is one of those phenomena that are of the core concern for both economists and biologists. William Forster Lloyd (1832) was perhaps the first economist who introduced the concept of "the overuse of a common by its commoners" (those with rights to access and use it), which was later developed by an American ecologist Garrett Hardin and termed "the tragedy of the commons". Hardin (1968) describes it as follows: "Each man is locked into a system that compels him to increase his herd without limit – in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest. We may well call it 'the tragedy of the commons', using the word

'tragedy' as the philosopher Whitehead used it: 'The essence of dramatic tragedy is not unhappiness. It resides in the solemnity of the remorseless working of things'".

Another example is "market signalling", the phrase and theory formulated by a co-recipient of the 2001 Nobel Prize in Economics Andrew Michael Spence (1973, 1974), reflecting the activities of individuals which are visible to somebody else and convey information in a market – a concept similar to "handicap principle" developed by a biologist Amotz Zahavi (1975, 1977).

2. Interactions between biology and economics – a historical perspective

The natural sciences (including biology) have interacted with social sciences (including economics) for a long time, and there is reason to believe that they would continue to do so. Below, the authors provide a historical account of the scientists and thinkers who have recognized the importance of biology for economics, and vice versa.

The ancient Greek philosopher and scientist Aristotle, who in his *Metaphysics* Book Zeta (Lewis, 2013) defines man as the rational animal, acknowledges both the continuity of humans with the rest of biological world and a clear qualitative distinction that sets human beings apart from it. According to him, "animal is universal to the species, man and horse, just in case (and only because) animal is contained in both man and horse". Additionally, Aristotle as a biologist applied scientific method to analyze political institutions (city-state and political rule), and affirmed the biological uniqueness of human political behaviour with his famous saying "man is, by nature, a political animal" (Aristotle, 350 BCE). Biology formed Aristotle's view of human happiness, the good life and telos (goal or end).

In 1705, Bernard Mandeville, an Anglo-Dutch philosopher and political economist, in his pamphlet entitled "The Grumbling Hive: or, Knaves Turn'd Honest"¹ found inspiration for economics in the complex order of the social insects (bees), presented as a metaphor for human society. In this work, which is regarded as a founding document of laissez-faire economic theory, he gives an analysis of how private vices result in increased public benefits.

According to a German writer, scientist and statesman Johann Wolfgang von Goethe, nature is perfect economy. The discipline he created in order to illustrate this was morphology. The

perfect economy was represented by natural budgets: "(...) *economical nature has prescribed a budget in which the main sum remains the same, for if too much has been given (expanded) on one side, it subtracts it from the other side and balances it out in no uncertain manner*" (Goethe, 1795). In other words, "*the budget of nature is fixed; but she is free to dispose of particular sums by an appropriation that may please her*" (Saint-Hilaire, 1818).

Adam Smith referred to the "economy of nature" in his "*Theory of Moral Sentiments*" (1759). Thomas Malthus (1789) borrowed from nature "*the laws of natural increase in the animal and vegetable kingdoms*" and noticed that taking the whole earth "*Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio*". Malthus' bioeconomics of population dealt with the issues of human survival: life and death.

The expression "economy of nature" was repeatedly used by a biologist Charles Darwin (influenced by Smith's economic writings) in his "*The Origin of Species*" (1859) and other publications. Darwin received some useful ideas for developing the theory of natural selection from Malthus' population principle. Darwin's theory of descent provides a general mechanism (i.e. natural selection) explaining the diversity and adaptiveness of living beings: "*All organic beings are striving to seize on each place in the economy of nature*", and "*natural selection is continually trying to economise every part of the organization*" (Darwin, 1859). He was one of the first scientists to suggest an explicit similarity between natural and political economy. With him, the economy of nature started to be understood with conceptual tools taken from political economy. The work division, resource scarcity, competition (struggle for existence), trading, an accumulation of innovations and the geometric population growth are ideas borrowed from Smith, Malthus and other founders of modern economics. The Darwin's theories indicate that

¹ Subsequent expanded version appeared under the title "The Fable of the Bees: or Private Vices, Publick Benefits" (Mandeville, 1714).

metaphors from economics have had crucial effect on the development of biology.

Alfred Marshall, one of the founders of neoclassical economics, turned to the biological evolution for inspiration in his *"Principles of Economics"* (Marshall, 1890). He believed that economic systems evolved akin to biological ones and that maximizing behaviour was prevalent due to the selection and survival of profit or utility maximizers (*"survival of the fittest"*) or since *"the natural selection of the strongest characters for a life of adventure"*.

Also Thorstein Veblen, a founder of old institutional economics, thought that social science had to be linked with biology (Jennings and Waller, 1998). According to him, *"It may be taken as the consensus of those men who are doing the serious work of modern anthropology, ethnology, and psychology, as well as of those in the biological sciences proper, that economics is helplessly behind the times, and unable to handle its subject matter in a way to entitle it to standing as a modern science"* (Veblen, 1898). He himself applied Darwinian ideas, namely principles of selection and inheritance as well as the principles of causality, in order to analyse socio-economic evolution. In the book entitled *"The Leisure Class"* he wrote: *"Institutions are products of the past process, are adapted to past circumstances, and are therefore never in full accord with the requirements of the present"* (Veblen, 1899).

According to Landa and Ghiselin (1999), modern bioeconomics with the rational choice emphasis emerged in the early 1970s and originates from the pioneering works of the public choice theorists: Gordon Tullock (1971) and Gary Becker (1976), a political economist Jack Hirshleifer (1977) and a biologist Michael Ghiselin (1978). It must be admitted, however, that before them influential Chicago School economists like Armen Alchian (1950) and Milton Friedman (1953) had proposed approach embodying the principles of biological evolution

and natural selection to interpret economic systems (including market) as an adoptive mechanism. Alchian's view is that neither profit nor utility maximisation but the criterion of *"realised positive profits"* guides the choice of action by economic agents and marks the success and viability. *"This is the criterion by which economic system selects survivors: those who realise positive profits are the survivors; those who suffer losses disappear"* (Alchian, 1950).

Gordon Tullock in his book *"The Economics of Non-Human Societies"* (1994) developed a general theory of society encompassing both human and non-human societies. In his analysis of non-human species, he applies the tools that have evolved in economics to explain human behaviour. Specifically, he raises the question of how the activities of the individual organism are coordinated in non-human economies. Answering, he says that each organism is programmed according to a preference function similar to the utility function postulated by the economists for human beings. Tullock's research on trust (1967) also contributed to bioeconomics, and thus, to the later development of neuroeconomics² viewed by some researchers as a natural extension of bioeconomics.

Summing up the literature review, it might be said that a research field called bioeconomics focuses chiefly on: (1) the significance of past evolutionary processes for studying current human behaviour; (2) the application of economic concepts and principles (such as competition, cooperation, specialization etc.) in studying biological phenomena, and (3) the incorporation of insights from biology (mainly evolutionary biology) into economic theory. On the one hand, some researchers (e.g. Tullock and Ghiselin) emphasize on what biology can learn from economics, admitting that there has been a

² The field of neuroeconomics seeks to discover the biological foundations of economic choice behaviour by investigating how current behaviour (decision making) is caused by ongoing brain processes.

persistent transfer of ideas and techniques from economics to biology but not believing (specially Tullock) that it is possible to learn much about human society from animal society. On the other hand, the others (e.g. Becker and Hirshleifer) argue that economics and biology can be mutually valuable; economics can accommodate insights from biology (mainly from evolutionary biology).

3. What is the bioeconomy?

Bioeconomy is an emerging concept which probably goes back to the OECD report (2001)

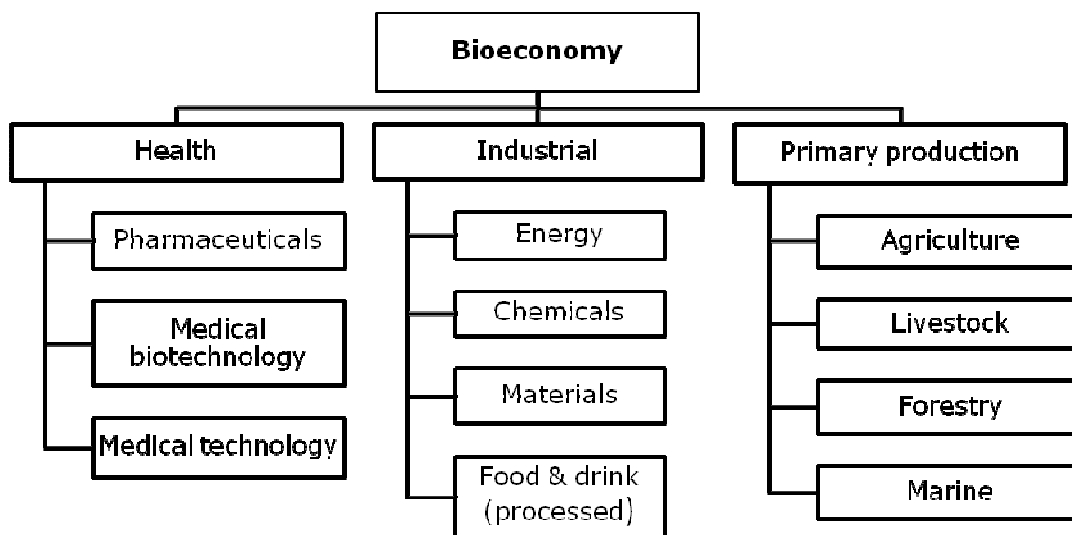
describing economy based on the use of renewable biological resources. In some literature, however, it is conflated with the notion of bioeconomics. In the opinion of the present authors, the bioeconomics should be seen from the theoretical perspective of economic science, while the bioeconomy either as some kind of political project (supported mainly by the European Union and the Organisation for Economic Cooperation and Development) or as specific sector of national economy.

Table 3

Selected definitions of bioeconomics

| Authors | Definitions |
|----------------------------|--|
| OECD, 2009 | The set of economic activities relating to the invention, development, production and use of biological products and processes. |
| The White House, 2012 | Economic activity that is fuelled by research and innovation in the biological sciences. |
| European Commission, 2012 | Encompassed production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy. |
| McCormick and Kautto, 2013 | An economy where the basic building blocks for materials, chemicals and energy are derived from renewable biological resources. |

Source: authors' construction based on literature review



Source: authors' construction based on Guy (2012)

Fig. 1. Sectors of bioeconomy

The study finds out that the definitions of the bioeconomy (more or less precise) differ depending on the source but display similarities such as an emphasis on economic activities (e.g.

production), a broad cross-sectoral and institutional focus as well as admitting the impact or role of technologies and knowledge derived from the biological sciences (Table 3).

The bioeconomy generally relies on life sciences, agronomy, ecology, food science, social sciences, biotechnology, nanotechnology, information and communication technologies, and engineering (EC, 2012). It includes primary production (of which the agriculture has a major role to play), industrial sector as well as health sector (Figure 1).

Conclusions and recommendations

- 1) Overall, the conclusions of this study are as follows.
- 2) Bioeconomics as a research and academic discipline can be interpreted at least in two ways: (1) as a vehicle for the adoption by the biological research community of ideas, approaches, concepts and tools (such as rational choice behaviour, maximization/minimisation under constraints, etc.) developed by the economists of different schools; (2) transporting analytical tools and

concepts developed in the biological sciences (particularly in the Darwinian evolutionary theory) into economic theory and practical research.

- 3) The terms bioeconomics and bioeconomy are not synonymous. The bioeconomy, as a set of specific economic activities and political project, can, however, borrow some insights from bioeconomics.
- 4) The perspectives and frameworks offered by bioeconomics give the opportunities for creative and novel interdisciplinary discourse between economic sciences and life sciences but also imply establishing closer, collaborative relations between them. In order to advance this field of research and academic discipline, economists and biologists need to work better together, while universities should offer students curriculum that incorporates economic subjects and biological subjects.

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