

Editorial

Towards an economics of the bioeconomy: four years later

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Abstract. This paper provides a summary of the evolution of the bioeconomy and compares it with trends in related economics literature. The objective is to discuss how the bio-based economics literature from recent years matches real world concerns and to emphasise emerging needs, in order to derive implications for economic research. Though 'bioeconomy economics and policy' is still far from being a well-established discipline, the current literature seems to recognise scope for its development together with (and contributing to) the development of the bioeconomy as a whole. Several emerging research areas are identified, ranging from the quantification of bioeconomy components and biomass flows, to the political economy of the bioeconomy. However, the economics of the bioeconomy needs most likely to develop not as an independent research area, but rather in close connection with the more 'traditional', but highly lively and innovating, areas of agriculture and food economics.

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1. Introduction and objective

In 2012, the newly founded Italian Association of Agricultural and Applied Economics (AIEAA) launched a new journal. After considerable discussion about the title of the journal, and its thematic focus within agriculture, food and economics, and their possible combinations and declinations, a proposal emerged for it to be dedicated to the bioeconomy and to take the name 'Bio-based and applied economics'. The idea was to look to the future and to situate the direction of the journal within the context of the most ambitious and widespread cutting edge concept in the field of biological resources economics, without however dismissing the more traditional areas of agriculture and food economics.

Since then, a good deal has happened in the world of the bioeconomy. The pathway has been marked by a number of major funding initiatives and by several major events. A

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major landmark event took place on 25-26 November 2015, when the Global Bioeconomy Summit was held in Berlin, bringing together more than nine hundred participants from around the world. The event, the first of its kind, brought to the stage a number of top speakers, including policy makers, scientists, religious leaders and entrepreneurs and has enabled the identification of key global strategic needs for the future bioeconomy (El-Chichakly *et al.*, 2016).

While a lot seems to be happening in the real world, what is economic research doing to match this evolution? Viaggi *et al.* (2012) envisaged a potential disciplinary shift from agriculture to bio-based economics and pathways for potential research developments in this direction. They also identified two broad areas of attention: i) the first is the bulk of specific research fields related to individual issues in the sphere of the bioeconomy: consumer sciences, markets, patenting rights, and innovation, as well as the economic and social aspects of bioenergy, biotechnologies and biomaterials; ii) the second is the need to address the broad concept of bioeconomy and to approach it in a comprehensive way from an economic perspective. Needless to say, the latter was already identified as the most challenging one.

This paper provides a summary of the evolution of the bioeconomy in the latest five years and compares it with trends in related economics literature. The objective is to discuss how the bio-based economics literature from recent years matches real world concerns and to emphasise emerging trends and needs, in order to derive implications for economic research. This is also an opportunity to support reflection on the role of the BAE journal in the context of the bioeconomy literature.

The remainder of the paper is organised in three main sections. Section 2 provides a review of recent trends in the evolution of the bioeconomy and section 3 summarises the advances in related economic literature. Section 4 provides a discussion and conclusions.

2. Policy context and perspectives

The policy context is characterised by growing concerns for climate change, scarce natural resources and world food needs. In parallel, there is growing recognition of the advances in technology, especially related to life sciences. In this context, the importance of the bioeconomy has grown considerably in policy agendas around the world. At least 45 countries now have policy agendas impacting directly on the bioeconomy, while at least 8 (including the EU and USA) have holistic bioeconomy strategies (German Bioeconomy Council, 2015a; 2015b).

The G7 countries have made considerable efforts to position themselves as leaders in this strategy. Germany, USA and Japan have produced the most ambitious bioeconomy strategies; the EU has taken a leading role in promoting the bioeconomy through its bioeconomy strategy and H2020 research framework programme (European Commission, 2012a; 2012b; German Bioeconomy Council, 2015a). Most EU countries now have national strategies on issues related to the bioeconomy and 18 out of 28 have the bioeconomy as a priority for EU structural funds.

Concrete steps have also been made toward qualifying the bioeconomy and its policy approach. There is a growing emphasis on the notion that the idea of bioeconomy alone is not necessarily ensuring improvements in welfare, and that efforts should be made to

target explicitly a concept of sustainable bioeconomy. This is emphasised in the final document of the Global Bioeconomy Summit (Global Bioeconomy Summit 2015, 2015) that recognises that a sustainable bioeconomy could make essential contributions to achieving the United Nations Sustainable Development Goals (SDG). The bioeconomy contribution is particularly focused on the SDGs related to food security and nutrition (Goal 2), healthy lives (Goal 3), water and sanitation (Goal 6), affordable and clean energy (Goal 7), sustainable consumption and production (Goal 12), climate change (Goal 13), oceans, seas and marine resources (Goal 14), and terrestrial ecosystems, forests, desertification, land degradation, and biodiversity (Goal 15), but it is also very relevant for sustainable economic growth (Goals 8 and 9) and sustainable cities (Goal 11) (Global Bioeconomy Summit 2015, 2015; El-Chichakli *et al.*, 2016).

Another important step in the policy context is the increasingly pronounced integration between the bioeconomy and circular economy strategies. The recent EU communication on the circular economy (European Commission, 2015) devotes one chapter to food waste and one chapter to biomass and bio-based products. Food waste is a major concern in the EU and a wide range of actions is expected (both at the EU and Member State levels). These actions range from common efforts toward improving food waste measures, to legislative initiatives supporting food donations or a better use of 'best before' labelling. The bioeconomy is expected to contribute to the circular economy, especially by providing alternatives to fossil-based products and energy, while it is recognised that bio-based materials can also offer advantages linked to their renewability, biodegradability or compostability. According to the communication, some of the main areas of interest include: a) the cascading approach to using bio-based resources, including food waste; b) the potential for innovation in new bio-based materials, chemicals and processes contributing to the circular economy; and c) the recycling of wood packaging and separate collection of bio-waste.

Bioeconomy strategies are also increasingly embedded in other policies, including the EU Common Agricultural Policy (CAP). For example, EU priorities for rural development, within priority 5 (promoting resource efficiency) also include: "(c) facilitating the supply and use of renewable sources of energy, of by-products, wastes and residues and of other non-food raw materials, for the purposes of the bio-economy".

According to the current definitions, the bioeconomy is one of the main components of the EU economy, with over 17 million jobs (8.5% of the EU workforce) and around 2 trillion euro of turnover. Food and agriculture remain the two main subsectors, but about 20% of bioeconomy employment and 25% of turnover are now generated by non-food and non-agriculture bioeconomy industries. Though the same statistics are not available for other areas of the world, bioeconomy sectors are already playing a key role in the economy of several large countries such as the USA, India, and Brazil. The share of bio-based products in world trade has raised from 10% in 2007 to 13% in 2014 (El-Chichakli *et al.*, 2016).

Information remains a clear constraint for more focused analyses of the bioeconomy. To fill this gap initiatives are under way, including the Bioeconomy Observatory launched by the EU Commission (<https://biobs.jrc.ec.europa.eu/>).

In spite of the lack of comprehensive data, it is already clear that the development of the bioeconomy in different areas of the world, while pushed by common needs, is also highlighting different approaches, as well as clearly competing interests. Some areas of the

world see the bioeconomy mostly as industrial or technological progress, while others see it in close connection with rural development, or as a way of exploiting their biological resources. There is a growing global interconnection in the effects of specific bioeconomy policies from one region of the world to another through global market forces, e.g. for the certification or protection of property rights on biological resources. To better address these issues, global awareness and global coordination in defining bioeconomy strategies is advocated (El-Chichakli *et al.*, 2016).

Looking at the future, on the heels of the Global Bioeconomy Summit, a Delphi study was carried out involving more than one hundred bioeconomy experts. It identified seven priority project areas for developing a sustainable bioeconomy, which are also a good proxy of the way forward in the development of the bioeconomy (German Bioeconomy Council, 2015c; El-Chichakli *et al.*, 2016): 1) new food and sustainable agri-food systems; 2) biosmart and integrated urban areas; 3) the next generation biorefineries; 4) artificial photosynthesis; 5) marine bioeconomy; 6) the development of consumer markets; and 7) international regulation and governance of the bioeconomy.

3. Advances in the economic literature

3.1 General trends

Searching “bioeconomy” in the Scopus database in July 2016 yields 479 papers, with a growing trend in recent years. Of these, 114 are classified in the category “social sciences” and 49 as “Economics, econometrics and finance”. Twenty-six are in “Business, management and accounting”. The most frequent are the 127 papers in “Biochemistry, Genetics and Molecular Biology” and 119 papers in “Agricultural and Biological Sciences”. Taking “Economics, econometrics and finance” only, the number of papers per year is (irregularly) growing over time: 8 in 2012, 9 in 2013, 4 in 2014, 17 in 2015 and 1 in 2016. Moreover, papers in economics tend to appear later than those in both the biological sciences and social sciences (the latter recording a good number of papers as early as 2004-2006).

Noteworthy special issues have been devoted to the bioeconomy in at least two major journals of agriculture and food economics (Agricultural Economics and the German Journal of Agricultural Economics) to complement several individual papers and at least one journal entirely dedicated to bioeconomy-focused works (AgBioForum).

In fact, the bulk of the bioeconomy-related economic literature relates to the individual building blocks of the bioeconomy. This is not surprising since some sectors have been extensively studied for decades and have a history that is much longer than the concept of bioeconomy itself. Some of these include well-established traditional sectors, such as agriculture and food. Some insights into these trends can be seen from publication numbers. Economics papers related to agriculture are now 10,213 in Scopus, and have grown constantly from 174 in 2000 to 756 in 2015. This is even more evident for economics papers related to ‘food’, now counting 12,954 papers in Scopus, having grown from 232 in 2000 to 1,187 in 2015. Clearly, these sectors are still attracting a good deal of attention and are even becoming more attractive topics for research.

More specific aspects of the bioeconomy are also the subject of a growing research effort, such as bioenergy, biorefinery, and biotechnologies. Economic papers indexed

in Scopus are now 1,357 for the “biotechnology” keyword (with a growing trend and average of more than 100 per year in the period 2011-2014) and 252 for bioenergy (with similar trends, though having started much later, and a production of about 40 papers per year in recent years). Biorefinery, for its part, only has 45 economics papers, with a top production of 10 in 2011 with subsequent ups and downs. One of the most interesting components of this group, involving newly emerging products such as bio-materials, still counts only 10 papers in economics (compared with more than 100 in business and tens of thousands altogether).

Investigating this large bulk of literature is beyond the scope and ambition of this paper. We rather focus on papers that are more oriented (or carrying some message) towards the bioeconomy as a whole and as a new concept. Based on the recent literature, some of the key areas of economic research in this direction are identified below.

3.2 *Scenarios and major driving forces*

The bioeconomy is driven by the perception of future needs as well as by opportunities generated by new technologies. Among the driving forces recognised as being instrumental in the push for the current and future development of the bioeconomy, the following areas of change play a key role: a) advances in related and complementary technologies, especially in biological sciences and information and communication technologies; b) challenges arising from a growing population and climate change, and related resource (fossil fuel, land, water) limitations; c) changes in the organisation of industries, including horizontal and vertical integration in agricultural supply chains, increasing inter- and intra-industry exchanges and the increase in the globalisation of the economy and product chains (Pätäri *et al.* 2016; Wesseler *et al.*, 2015). The highly dynamic nature of these drivers creates a continuous need for scenario development and technology forecasting. Both the identification of these driving forces and the role they can play for the future bioeconomy are investigated in the literature, as well as the understanding (measurement) of the future needs they entail and the potential and credible strategies for the bioeconomy to deal with these needs.

3.3 *Definition and conceptualisation of the bioeconomy*

The definition of the bioeconomy and its boundaries is a particularly difficult task given the number of interconnections that it embodies, both as a concept and as a sector. The definition of the bioeconomy in itself is largely driven by policy action and the contents of bioeconomy strategies worldwide, such as the list of sectors addressed (see section 2).

With regard to research, the problem that has emerged is that of understanding and qualifying the concept(s) of bioeconomy. This has been largely addressed by exploring the connection between the bioeconomy and surrounding concepts: sustainability, circular economy, ecosystem services, green economy, and agroecology. In this respect, the bioeconomy as a political vision is more and more often specified as a “sustainable and circular bioeconomy”. From a purely conceptual (but also cultural, political and economic) point of view, one stimulating as well as confusing aspect is that the concept itself is

developing in a context characterised by the emergence of a number of “bio-concepts” which, in a way, makes it even more difficult to identify a common understanding of the bioeconomy (and, for that matter, bioeconomics) (Birch and Tyfield, 2012).

The term bioeconomy, on the other hand, is used to identify different ‘types of objects’, notably ranging from a list of sectors to, more ambitiously, a new development model. One of the most politically and conceptually relevant distinctions is the demarcation between a territorial view of the bioeconomy and a more process-oriented (industrial) interpretation of the bioeconomy (Schmidt *et al.*, 2012). With a different perspective, these contrasting views also apply to one of the most qualifying concepts linked to the bioeconomy, namely that of biorefinery (Ceapraz *et al.*, 2016).

3.4 Describing the bioeconomy: cases studies, experiences, policies, and measurement

It is common for fields of study at their inception, to build a lot on ‘simple’ observation. A number of studies address the issue of the bioeconomy by describing and analysing case studies of bioeconomy development. These may be related to specific policies, country strategies (e.g. Kamal and Che Dir, 2015), or to specific plants (e.g. Schieb *et al.*, 2015). However, as the subject is still being developed, the measurement of specific bioeconomy features is also developing and shaping the specificities of the bioeconomy. The most relevant cases include:

- Quantification of biomass flows, especially in relationship to industry needs (in terms of quantity, quality and location), to the ability of agriculture and the forestry sector to meet future demand for biomass, and in connections with resource use (see also section 3.7 below) (Kalt, 2015);
- Quantification of waste and by-products and circular flows into re-use, in connection with the idea that the minimisation of waste and re-use is in fact one of the key concepts in a circular bioeconomy (Cardoen *et al.*, 2015);
- Analysis of the degree of circularity, closely connected to the quantification of waste and by-products, but also of interest on its own; this area of research also highlights several specificities of biomass in terms of (lack of) potential for re-use and of the ability to close the physical loops, which is connected to the cycle of different resources, such as fertilisers (Haas *et al.*, 2015);
- Uptake of specific bioeconomy technologies, e.g. GMOs, biotechnologies in general, or those based on biomaterials which may in fact be connected to a growingly intricate network of intersectoral relationships;
- Investment of venture capital in the biotech and bioeconomy industries, which is relevant both as an indicator of economic attractiveness and as an indicator of innovation effort; this is also a field in which it may be possible to identify the specificities of the sector in terms of research investment and innovation financing (Festel and Rammer, 2015).

3.5 Political economy of the bioeconomy and transition analysis

Given the difficulties that some key bioeconomy technologies, most notably GMOs, face in navigating their way through political legitimation and public acceptance, the

political economy of the bioeconomy is emerging as one of the most focused economic research areas applied to the bioeconomy. A special issue of the German Journal of Agricultural economics was dedicated to this topic (Wesseler *et al.*, 2015; Zilberman *et al.*, 2015; Pannicke *et al.*, 2015; Puttkammer and Grethe, 2015). The authors stress several points, including the importance of understanding and representing explicitly the interplay within different stakeholder groups and the usefulness of insights from behavioural economics, especially in connection with how to approach unknown futures.

The need for a dynamic framework is also highlighted. The use of a dynamic approach leads to the use of the perspective devoted to the process of making the bioeconomy real through transition analysis, understanding how major changes in technologies may become possible through different steps and enabling conditions (Pannicke *et al.*, 2015).

3.6 *Technology, innovation and technology transfer*

Technology is one of the main focuses of the bioeconomy; from the perspective of technology, the bioeconomy can be viewed as a continuing evolutionary process of transition from systems of mining non-renewable resources to farming renewable ones (Zilberman *et al.*, 2013). Its evolution is strictly linked to funding research and innovation to develop new and improved technologies in this direction. The landscape of research and link to technology production and transfer is a key object of research in bioeconomy studies (Golembiewsk *et al.*, 2015; Festel and Rittershaus, 2014). Similarly, noteworthy attention is being devoted to technology transfer processes, including in connection with agriculture knowledge systems. Technology is also relevant in terms of the connections between different goods on the supply side and related costs. Finally, technology can be addressed from the perspective of the specificities of bioeconomy technologies and how they can be represented in economic studies (Viaggi, 2016).

3.7 *Biomass supply and resource use*

The future need for biomass will put pressure on resources needed for its production; a widely explored field focuses on the ability of resources to meet biomass demand, and the transformation, including technological improvement, to match such needs. Among others, land is the primary resource under pressure, but increasing attention is being paid to alternative sources of biomass, e.g. seas. There is also an increasing focus on the need for water and fertiliser (especially non-easily renewable ones, such as phosphorous), which are the main other factors needed for vegetal production (Hertel *et al.*, 2013; Rosegrant *et al.*, 2013).

3.8 *Markets and their connections*

An area of study that is linked to the previous one relates to the connection between markets. Market connections go beyond meeting demand, but also relate to qualifying market relationships. For example, topics include price stability (and the transmission of

instability) or vertical and horizontal integration. One market connection that has already been in the spotlight is the connection between energy and food products, as part of the discussion about the energy-food nexus (Lochhead *et al.*, 2016). The issue is however much wider as long as a number of bioeconomy technologies tend to substitute existing products and/or create links between different value chains.

On the other hand, for products that do not have a market yet, the issue is how to smoothly create new markets. This is a clear policy concern in most of the policy documents available and in research and innovation funding (including H2020).

In the context of markets, consumer analysis and behaviour is one of the big focuses of attention of economic research. Specific bioeconomy issues related to food (e.g. GM crops) have dominated, but the issue at hand is much larger and even more important in perspective. It does not only implies understanding consumer preferences, but also includes investigating consumer awareness and new models of connection between supply and demand (Viaggi, 2016).

3.9 Tools and management

While the sector is developing steadily, much can be learned from one of the most practical needs, namely the development of tools for the evaluation of the potential impacts of new technologies. In this respect, Life Cycle Assessment (LCA) has rapidly developed as a key tool for technology analysis, to answer the growing need to account for a product chain view of the need for new technology assessment and to consider specific bioeconomy issues, such as the allocation of impact across multiple products and by-products, as well as circular flows (Ness *et al.*, 2007; Sandin *et al.*, 2015; Tilche and Galatola, 2008). Furthermore, environmental management tools are pervasive and are increasingly seen as key instruments for the sustainable management of bioeconomy sectors (Straczewska, 2013).

3.10 At the boundary of economics

At this point in the inception of the sector, a good deal is actually happening at the boundary of economics, with a number of potential points of contact between economics and politics, sociology, law, governance, and communications, just to mention a few.

A direct focus of attention is politics and the interpretation of the push for bioeconomy development as a mainly political process to ensure the survival of current capitalist structures (Goven and Pavone, 2014). A clearly very important aspect is regulation, which has also been the subject of a growing number of studies. The regulation of new technologies has been at the forefront, including regulation as a way to ensure the compatibility between profitability and economic, social and environmental objectives related to bioeconomy technologies (Wessler *et al.*, 2010).

4. Discussion and implications

The Global Bioeconomy Summit highlighted the fact that the bioeconomy as a whole is a growing economic and development strategy the world over, while statistics

underscore its large and growing role in the economy. There is a latent divergence between two notions of bioeconomy: one that basically uses the term as the non-food component of the economy linked to biological resources, and another that also includes agriculture and food. Policy trends in the EU and worldwide seem to legitimate the second option.

Bioeconomy research, for its part, tends to maintain a focus on a number of promising topics, though largely focused on very narrowly defined problems and scientific fields. One clear message that arises is the need for a more comprehensive view of the bioeconomy that is able to address the challenges of the interconnections among different components of the bioeconomy, different regional needs and different expectations.

This demand also involves research and, while this may be common to all disciplines, it is especially true for all economic research. The literature has begun to mention an “economics of the bioeconomy” (Viaggi *et al.*, 2012) or a “bioeconomy economics and policy” (Wesseler *et al.* 2015). However, attention remains particularly focused on individual sectors such as agriculture and food, and, to a lesser extent, biotechnology or bioenergy. This is largely justified by the individual relevance of these sectors, but also by their role in the development of the bioeconomy, and is measured by a steadily growing number of publications in these fields, especially food and agriculture. This is not again the development of the idea of bioeconomy. Indeed, myriad issues in the bioeconomy discussion directly concern agriculture and the development of agriculture is seen as a key step in the development of the bioeconomy. The emphasis on the bioeconomy and world food needs have given prominence to, and raised interest in, the sector, hence encouraging a renewed emphasis on its economic analysis.

Looking at current trends in the economy and in research, it is clear that the development of the bioeconomy requires research with multiple scales and scopes. On the one hand, focused studies, starting from basic profitability, consumer attitudes, technology assessment and business model analysis are needed in specific bioeconomy sectors. On the other hand, holistic approaches are needed to ensure the integration of bioeconomy in a territorialised economy, where the ecosystemic, social and public good dimensions of the bioeconomy are also perceived as relevant. Furthermore, both sector and multi-sector approaches are needed. These different views could feed each other through more attention to new linkages between sectors and product chains, which are one of the structuring features of the bioeconomy.

Altogether, ‘bioeconomy economics and policy’ is still far from being a well-established discipline. However, the current literature seems to recognise scope for its development together with (and contributing to) the development of the bioeconomy as a whole. This confirms the appropriateness of the choice of the focus on “Bio-based and applied economics” for this journal, but also highlights that giving meaning to this choice remains an open challenge and will need ‘pragmatic dialogue’, rather than (or perhaps in order to achieve) a ‘paradigmatic shift’, with the more traditional fields of agriculture and food economics. This also validates the choice of a flexible scope and hints at this being even more the case in the future.

Having said that, maintaining continuous reflection on the bioeconomy as a subject of research and a shaping delimitation for economic thought is also a worthwhile challenge. Each of the research areas identified in this paper are merely at the inception level and

may in fact represent suitable directions, though still largely undefined, for further research in this field. Among them, technological specificities, the conceptualisation of the bioeconomy, linkages among bioeconomy sectors (in terms of both technology and markets) are key areas of economics in which research is highly needed for the development of the bioeconomy. In this respect, a further challenge for economics would be to move from a mainly descriptive and interpretative perspective, to a more proactive and normative approach, seeking to provide a more direct contribution to private decisions and policy support in the bioeconomy.

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