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Editorial

Sustainability Transition towards a Biobased Economy: Defining, Measuring and Assessing

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Abstract: This Special Issue proposes an array of 11 key papers aimed at investigating the complex and multifaceted nature of the biobased economy, focusing both on a conceptual understanding of the transition and on the measurement issues associated to it. More specifically, collected papers can be broadly divided in two groups: (1) those aiming at adding to our understanding of the transition process towards a sustainable biobased economy; and (2) those aiming at adding to the definition and measurement of the emerging sustainable biobased economy. In the guest editor view, papers collected in this Special Issue offer valuable and complementary insights to our understanding of the ongoing transition towards a biobased economy, providing a logical framework to understand the transitions, as well as an overview of existing tools to assess and measure it. Ideally, policy makers will benefit from the papers included in this Special Issue and, hopefully, it will contribute to make a further step to the much-needed transition towards sustainability.

Keywords: biobased economy; sustainability transition; standards; indicators

1. Introduction

It is widely acknowledged that, currently, two economic models co-exist, side-by-side, i.e., the dominant fossil-economy and the emerging biobased economy. The rise of a new biobased economic model underlines the need to undergo a paradigm shift towards sustainability in order to meet society's long-term goals and emerging challenges, which include the following: decoupling economic growth from environmental pressure, managing natural resources in a sustainable way, improving food security, reducing poverty, etc. Although sustainability has become a core theme of innovation economics, strategies for achieving this goal—and hence, for supporting the paradigm shift—remain under-investigated, mainly due to the complexity related to the manifold nature of the concepts involved.

Among others, key drivers of this paradigm shift (or transition towards sustainability, we might say) involve the following: (1) development and diffusion of new green technologies (eco-innovations) for a biobased economy; (2) development of a holistic approach for sustainability assessment of biobased products (e.g., sustainability schemes, standards, and eco-labelling initiatives); (3) policy measures for promoting market uptake of biobased products and creating a level playing field among biobased products and conventional (fossil-based) alternatives.

However, before looking closely at these leveraging points we need to better define the biobased economy first, and properly measure it, subsequently. The lack of agreed-upon definitions, as well as measurement tools, can be explained by the complex nature of the phenomenon under investigation. Indeed, the biobased economy sits at the intersection of many overlapping concepts, including sustainable development, circular economy, and green technologies, which are complex notions on their own.

Hence, initiating a transition towards such a new socio-economic paradigm (i.e., based on biomasses and circularity principles) is not just a matter of scaling-up an innovative technology that has emerged in a niche [1] (p. 63), but rather it involves the emergence of a new and complex set of relations among stakeholders acting at the production level, as much as the consumption level. These intersect with institutional actors playing a fundamental role in steering the transition process altogether.

In order to account for these complex relations, the literature on sustainability transitions (see, among many others) [2], has argued in favor of adopting a multi-level perspective (MLP), where socio-technical changes are seen as the outcome of a combined pressure exerted upon the incumbent dominant technological regime (i.e., the meso-level), operated simultaneously from the landscape level (i.e., the macro-level consisting of a set of deep structural trends) and the technological niche level (i.e., the micro-level where new technologies are developed in a protected environment).

Stemming from these considerations, this Special Issue proposes an array of 11 papers aimed at investigating the complex and multifaceted nature of the biobased economy, focusing first on a conceptual understanding of the *transition* and, subsequently, on the measurement issues associated with it.

Papers included in this Special Issue provide contributions coming from researchers trained in hard sciences (chemistry, agronomy, engineering) as well as in social sciences (economics, management, policy analysis). This broad spectrum of academic knowledge is well complemented by more applied perspectives coming from international institutions, NGOs, consultants, and independent analysts. This plurality of voices gives the reader an overall picture of the transition towards a biobased economy, highlighting the mounting complexity characterizing the system under investigation. Papers collected in this Special Issue can be broadly divided in two groups: (1) those aiming at adding to our understanding of the transition process towards a sustainable biobased economy; and (2) those aiming at adding to the definition and measurement of the emerging sustainable biobased economy. In the first case, authors often take a country-specific or a sector-specific perspective to resolve the complexity of the challenge. In the second case, a European-wide (or even worldwide) outlook is often privileged as well as a life-cycle perspective that spans from feedstocks' procurement to end-of-life options.

2. Understanding Sustainability Transition Pathways to a Biobased Economy

Four papers of this Special Issue broadly refer to the transition process, with a sectoral focus on transition pathways.

Bennich et al. [3] focus their attention on the Swedish agricultural sector, attempting to identify "high order leverage points", which could best initiate a systemic change. Authors provide valuable insights on the social and ecological processes contributing to or hindering the transition in this sector. The analysis is performed using a combined methodology that relies on systems analysis and expert interviews, and concludes that the assumption that a transition process would necessarily entail an expansion of agricultural production for the purpose of growing crops for non-food biomass applications is challenged. As shown by the authors, different pathways have different implications in terms of biomass demand and supply, and, depending on the objectives set by the policymaker, alternative pathways should be supported.

In a subsequent paper, Bennich et al. [4] use a similar twofold methodology for the forestry sector in Sweden, assessing potential future transition pathways. Desired change processes identified include a transition to diversified forest management, a structural change in the forestry industry to enable high-value added production, and increased political support for the biobased economy concept. Hindrances identified include the difficulty in demonstrating the added value for end users of novel biomass applications, and the uncertainty linked to a perceived high level of polarization in the forestry debate.

Alaerts et al. [5] focus on biobased plastics and assess how the introduction of these new polymers in a circular economic model could disturb the current recycling of fossil-based plastics, inhibiting

the closure of plastic cycles. This is a rather relevant research question to address in order to assess how the co-existence of the two economic systems mentioned in the introduction (the fossil-economy and the emerging biobased economy) might produce unexpected side effects, hindering the transition pathway. As claimed by the authors, the co-living with the recycled fossil-based plastics presents no risks for biobased plastics as a group. However, several potential sources of contamination arise when considering separately different bio-polymers. For instance, PLA (polylactic acid) shows a severe incompatibility with PET (polyethylene terephthalate); hence, future risks are assessed by measuring the amounts of PLA ending up in PET waste streams. For PHA (polyhydroxy alkanoate), there is currently no risk, but it will be crucial to monitor future application development. Bearing this in mind, the authors stressed that any introduction of novel plastics must be well guided from a system perspective, properly pondering incompatibilities with current and upcoming practices in the recycling of plastics.

Urmetzer et al. [6] underline the knowledge dimension associated with the biobased economy transition. Taking an innovation systems (IS) perspective, the authors claim that, to successfully contribute to a sustainability transition, a knowledge-based bioeconomy should broaden its scope beyond the techno-economic dimension. Along this line of reasoning, the authors propose to include systems knowledge, normative knowledge, and transformative knowledge in research and policy frameworks for a sustainable knowledge-based bioeconomy (SKBBE). In order for policy makers to be able to effectively steer the bioeconomy transformation onto a sustainable path, the authors claim that a stronger focus on the characteristics of *dedicated* knowledge (including stickiness, locality, context specificity, dispersal, and path dependence) and its creation, diffusion, and use are necessary for the knowledge-based bioeconomy to become truly sustainable.

3. Measuring the Biobased Economy

Measurement issues associated with the biobased economy have been addressed both at the macro and micro levels. Specifically, two papers focus on indicators to measure the biobased economy as a whole, whereas the remaining five focus on value-chains and specific biobased products.

When looking at macro data, Ronzon and M'Barek [7] observe how the monitoring of the European biobased economy is hampered by a lack of statistics on emergent and partially biobased sectors (i.e., those sector where biobased products are produced along non-biobased products). The authors, to tackle this issue, propose a simplified socioeconomic indicator framework for the bioeconomy in the EU. Subsequently, they use the proposed indicators to assess economic performance through a labor productivity measure. This exercise provides insights related to the growth potential of specific bioeconomy sectors in individual EU Member States. The authors first position Member States on a transition path to higher productivity and, subsequently group them looking specifically at the East-West bioeconomy disparities within Europe; these leads to the suggestions of a set of measures to promote the development of the EU biobased economies.

Bracco et al. [8] move from the observation that, worldwide, most countries focus on the contribution of the bioeconomy sectors to gross domestic product (GDP), turnover, and employment. However, this approach offers an incomplete picture as environmental and social aspects, which are unanimously considered as fundamental pillars of the biobased economy, are dropped from the analysis. Bearing this in mind, the authors provide a critical assessment of the national methods used for the measurement, monitoring, and reporting of the bioeconomy contribution to the total economy. The analysis, based on research and surveys conducted on six countries (Argentina, Germany, Malaysia, The Netherlands, South Africa, and the United States), shows the lack of a homogenous definition of bioeconomy across the six considered countries—a fact which hinders any straightforward comparison of the relevance of bioeconomy in the different economies. Moreover, as observed by the authors, the bioeconomy targets set by nation-wide strategies often reflect the country's priorities and comparative advantages linked, for instance, the availability of natural resources, traditional industries, labor productivity, and past investments in R&D.

In order to improve the measurement and monitoring of the bioeconomy, the authors call upon national governments to enhance and coordinate communication among domestic agencies, establishing protocols for sharing data, formalizing biobased industry measurement standards, developing a comprehensive survey for the biobased industry and commodity usage, and improving industry classification systems.

Moving down to the micro level of analysis, Lokesh et al. [9] present a mapping exercise aiming, first, at identifying the most relevant biobased value chains to attain a fully functional biobased circular economy, and subsequently, at visualizing/foreseeing the strengths, weaknesses, opportunities, and challenges associated with it. Value chains selection was done by means of a two-step methodology based on multi-criteria decision analysis. The selection process led to the identification of five key value chains, for each of which specific maps were developed. As claimed by the authors, this exercise demonstrates the highly informative nature of this tool and its crucial role in understanding the complex interactions among the various processes and stakeholders within complex bioeconomy value chains.

Both Falcone and Imbert [10] and Martin et al. [11] look at a specific dimension of sustainability, i.e., the social one. As mentioned earlier, this is an area often neglected in sustainability assessment and, indeed, deserves greater attention. Falcone and Imbert [10] provide an overall assessment of social impact categories and indicators that should be included in a social sustainability assessment of biobased products. The study is performed following a three-step methodology. First, the authors carry out a literature review on existing social life cycle studies, identifying most relevant social categories and indicators. Subsequently, the categories' list and indicators are validated with the help of a focus group bringing together industrial experts and academics. Finally, a zoom-in into consumers' perceptions of social indicators was obtained by conducting semi-structured interviews with consumer representatives. Results showed the need to better exploit consumers' role in the ongoing process of market uptake of biobased products. More specifically, this need entails the effective inclusion of some social indicators (i.e., end users' health and safety, feedback mechanisms, transparency, and end-of-life responsibility) in the social life cycle assessment scheme for biobased products.

On a similar ground, Martin et al. [11] review the scientifically published life cycle studies on biobased products, investigating the extent to which they include important sustainability indicators. Results suggest that there is a discrepancy between the indicators considered important in established frameworks for sustainability assessments, and the indicators that are frequently included in published scientific studies. The authors suggest that greater attention should be paid to categories such as workers conditions, water depletion, indirect land use change, and impacts on ecosystem quality and biological diversity—all elements noted as very relevant also by the United Nations (UN) Sustainable Development Goals.

The last two papers of this Special Issue are dedicated to certification and standards for the emerging biobased economy. Majer et al. [12] performed a rather impressive gap analysis in order to assess the current status of sustainability certification and standardization in the biobased economy. The methodology used was twofold, involving a comprehensive desk analysis complemented by expert interviews. The analysis revealed an impressive amount of existing certification frameworks, criteria, indicators and applicable standards. However, the authors identified major gaps in: (1) existing criteria sets; (2) the practical implementation of criteria in certification processes; (3) the legislative framework; (4) end-of-life processes; as well as (5) necessary standardization activities.

Fonseca and Domingues [13] take a narrower view, focusing on a specific standard (ISO 14001:2015) and assessing the transition towards the revised version of the voluntary environmental management systems (EMS) certification scheme among Portuguese organizations. By means of an on-line survey, the authors collected data on 108 organizations. Respondents viewed *Determination of risks and opportunities* and the *Life cycle perspective* as both the most useful concepts of ISO 14001:2015 but also as the hardest difficulties to overcome by the organizations when implementing or transitioning to the 2015 edition of ISO 14001. Indeed, those organizations that

successfully completed the transition reported benefits, with an enhanced environmental performance of the organization and an improvement in the compatibility with other management system standards, such as ISO 9001. Authors also observed that the perception of the benefits achieved with ISO 14001:2015 certification varies with the size of the organization, whereas the motivation to proceed with certification is independent of organization profile.

4. Concluding Remarks and Further Issues on the Research Agenda

This special issue has succeeded to collect eleven key papers addressing, from different angles, the topic of a sustainability transition towards a biobased economy. Contributions include research by European academia, research centers as well as international organizations and institutions. The plurality of voices shows the growing interest around this topic in Europe. Major efforts have been invested to foster the transition both at the single Member State level and at the European Commission level. Since 2012, Europe has adopted a strategy for the bioeconomy that is currently undergoing a revision process to ensure that Europe focuses its efforts in the right direction. As stated by the Commission, "*Bioeconomy is Europe's response to key environmental challenges the world is facing already today. It is meant to reduce the dependence on natural resources, transform manufacturing, promote sustainable production of renewable resources from land, fisheries and aquaculture and their conversion into food, feed, fibre, biobased products and bio-energy, while growing new jobs and industries*". This statement shows a strong commitment to reduce the impact on the environment without compromising on job creation and "healthy" economic growth.

For these objectives to be simultaneously achieved, major efforts are needed in defining properly the target and setting the right policy to reach it. Yet, technological uncertainty makes the bioeconomy a moving target, hence continuous adjustments are required to hit it. In this regard, papers collected in this Special Issue make a useful contribution by providing a logical framework to understand the transitions, as well as existing tools to assess and measure it. Ideally, policy makers will benefit from the papers included in this Special Issue and, hopefully, it will contribute to making a further step to the much-needed transition towards sustainability.

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