Developing Improved Tools for the Economic Analysis of Innovations in the Bioeconomy: Towards a Life Cycle-Strengths-Weaknesses-Opportunities-Threats (LC-SWOT) Concept?

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Abstract

The bioeconomy is one of the areas with the greatest innovation potential and also the highest degree of complexity, in relation to both the articulation of technologies using biological resources and the range of human values involved. As a result, this area of the economy increasing calls for the early evaluation of new technologies both from a business and societal perspective. The objective of this paper is to review the literature on the existing instruments designed to provide an (economic) analysis of new technologies in the bioeconomy sectors (in particular the well -known concepts of Life Cycle Analysis - LCA and Strengths-Weaknesses-Opportunities-Threats -SWOT), and to devise avenues for the improvement of such instruments. Specifically, the paper focuses on developing the idea of a Life Cycle-Strengths-Weaknesses-Opportunities-Threats methodology (LC-SWOT) as a potential tool for improving the ability to evaluate early stage technologies in relation to the entire technology/product life cycle.

Keywords: bioeconomy, LCA, SWOT, LC-SWOT, technology evaluation, innovation

1. Background and Objectives

In the coming decades, humanity is expected to face several major challenges, including an increase in the world's population, in particular in emerging countries (China, India), a further concentration of people in towns and cities, the ageing of the population in developed countries, and an increase in incomes and related changes in consumption habits. This will cause a growing demand for food, energy and health services, to be obtained at reasonable costs, in a context characterized by increased global competition and resource scarcity, at the same time without compromising the fight against climate change.

In such a context, innovation has been placed at the heart of the EU strategies as emphasized by the Europe 2020 strategy and by the Innovation Union flagship initiative (European Commission, 2010a, b). In this context, the concept of the bioeconomy (or bio-economy or bio-based economy) has been put forward as the guiding perspective concerning primary production based on the management of biological resources. The bioeconomy has been defined in a number of different ways in various policy documents issued in recent years (see e.g. Clever Consult BVBA, 2010; OECD 2009). The word bioeconomy itself has often been introduced in the economic disciplines, yet for rather different concepts. The EU communication "Innovating for Sustainable Growth: a Bioeconomy for Europe" and its accompanying working document (European Commission 2012a; b) qualify the Bioeconomy as encompassing "the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy. It includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries. Its sectors have a strong innovation potential due to their use of a wide range of sciences (life sciences, agronomy, ecology, food science and social sciences), enabling and industrial technologies (biotechnology, nanotechnology, information and communication technologies - ICT, and engineering), and local and tacit knowledge." A narrower definition is used by the OECD (2009): "…the bioeconomy can be thought of as a world where biotechnology contributes to a significant share of economic output." In projecting the future of biotechnology and the bioeconomy up to 2030, this study identifies three key elements characterizing this sector: a) an advanced knowledge of genes and complex cell processes; b) renewable biomass; c) integration of biotechnology applications across sectors.

The bioeconomy in the EU (using the EU definition) presently accounts for an annual turnover of 2046 billion euro (of which 965 from food and 381 from agriculture) and 21 505 thousand employees (of which 4400 thousand in the food industry and 12 000 thousand in agriculture) (Clever Consult BVBA, 2010).

The bioeconomy is believed to be able to play an important role in creating economic growth and providing responses to global challenges, hence contributing to a smarter, more sustainable and inclusive economy. However, the different scientific contributions with regard to the potential for the future development of the bioeconomy (Carlson, 2007, OECD, 2009; May, 2009; The Royal Academy of Engineering, 2009) show rather diversified estimates of development, in particular in relation to the many variables that can affect such development. The OECD (2009) identifies 4 drivers for future development of the bioeconomy: 1) public support to biotechnological research and training of young researchers; 2) public regulation; 3) management of intellectual property; and 4) public acceptance of biotechnologies. Innovation in public policy is recognised to have a central role across such determinants due to the apparent inability of market mechanisms and the present policy framework to guarantee a suitable response to future needs. The BECOTEPS (2011) white paper emphasises that a "successful bioeconomy needs coherent and integrated policy direction", with key areas including investment in research, encouraging innovation, strengthening entrepreneurship in the bioeconomy, providing a skilled workforce, guaranteeing an innovation-friendly regulatory framework which balances both risks and benefits, and a good two-way communication with the public embedded in R&D projects to ensure societal appreciation of research and innovation. The documents of the main European Technology Platforms highlight, in particular, the need for an increased understanding of the concerns of consumers and citizens, as well as initiatives aimed at improved communication. The recent communication about resource-efficient Europe encourages to consider the whole life cycle of the way resources are used, including the value chain, and the trade-offs between different priorities.

The need to widen the view of the evaluation of emerging technologies and products is proving to be a challenge for firms and practitioners. This includes research staff involved in bringing economic support to research projects oriented toward the development of new technologies. While several methods are available in the (economic) evaluation toolbox, most of them seem to have several limitations in addressing this issue. For example, cost and profitability evaluations, while useful, are often unreliable due to the fact that: a) the profitability of a given technology may be determined by consistent adaptations of several other technologies; and that b) profitability is determined by a mix of social acceptability and market building operations, including feedback and threshold effects.

Market analysis tools can be used; however, they restrict attention to contingent consumer perceptions of products, without considering the wider societal perception or the variability of consumer preferences in relation to changing information sources.

A very often used instrument from management science and practice is the SWOT (Strength-Weaknesses-Opportunities-Threats) analysis. This tool provides a soft qualitative analysis of the potential and the limitations of emerging products. In contrast to this, or more often as a complementary piece of analysis, the LCA (Life Cycle Assessment) approach is proposed to fully account for detailed environmental issues throughout the product life cycle.

The objective of this paper is to review the literature on selected existing instruments designed/used to provide an analysis of new technologies in the bioeconomy sectors (in particular those related to food production, and focusing on LCA and SWOT), and to devise avenues for the improvement of such instruments. Specifically, the paper focuses on developing the idea of a Life Cycle-Strengths-Weaknesses-Opportunities-Threats methodology (LC-SWOT) as a potential tool for improving the ability to evaluate early stage technologies in relation to the entire technology/product life cycle.

The paper argues that there is a convergence over time between the LCA and SWOT approaches, and that the joint use of concepts from both methods can help to develop improved instruments for early technology evaluation.

The paper is developed through three main steps. In the next section, a review of the literature on evaluation instruments is provided. This is followed by the illustration of the LC-SWOT methodological proposal. Then, extensions and potential developments are illustrated. The paper concludes with a discussion and conclusions.

2. Selected Literature on LCA and SWOT

LCA and SWOT are two widely proposed approaches to provide judgments about the sustainability of new technologies. Surprisingly, however, they have rarely been used together. Searching the ISI Thomson database for

"LCA and SWOT", only one paper applying both methods is found. In this paper (Maydl et al., 2007), LCA and SWOT are used in parallel: the LCA serves to provide an ecological assessment of steel for construction, while the SWOT analysis is used to carry out a pre-feasibility study as well as to identify a future call for action for the steel construction industry. Both methods are used in a comparative manner, comparing three office buildings with different load bearing systems.

Let us now consider the two methods separately.

Life cycle assessment (LCA) is a well-known methodological framework for estimating and assessing the environmental impacts attributable to the life cycle of a product, using a ''cradle to grave'' approach, i.e. including raw material extractions, energy acquisition, materials production, manufacturing, use, recycling, and ultimate disposal. The key step in an LCA is the compilation of associated emissions and resource consumption in a life cycle inventory (LCI). This step already implies defining and modelling a product's life cycle and collecting appropriate information (Rebitzer et al., 2004).

A subsequent major step in the methodology is the impact assessment. This includes the models and methodologies allowing to calculate and compare indicators of the potential impact contributions associated with the wastes, emissions and resources consumed that are attributable to the provision of the product in a study (Pennington et al., 2004). While this generally focuses on environmental impacts, several methods proposed in the literature and pursued as relevant avenues for future research have their origins in socio-economic analysis, e.g. the monetary evaluation of environmental impacts, or multicriteria techniques to summarize a product's impacts (see Pennington et al., 2004 for a non-exhaustive review).

In addition, ISO 14040, which provides the standard for LCA, points to the further need for a step that includes the interpretation of the results and their contribution to decision-making, including product development, strategic planning, public policy making and marketing (Rebitzer et al., 2004).

LCA is increasingly used (or at least proposed) in the analysis of food chains (see Roy et al., 2009 for a review) and other biobased products. For example, Kemppainen and Shonnard (2005) use LCA to evaluate the performance of 'Biomass-to-Ethanol Production from Different Regional Feedstocks'.

A particularly promising field is the use of LCA information as a basis for marketing food products.

The SWOT (strengths, weaknesses, opportunities and threats) analysis is used more than any other management technique in the process of decision making. It was developed between the 1950s and the 1960s as a major advance in strategic thinking. The SWOT analysis focuses on the analysis of an organisation's internal and external environment with the aim of identifying internal strengths in order to take advantage of its external opportunities and avoid external threats, while addressing the organisation's weaknesses (Panagiotou, 2003; Ghazinoorya, 2011).

Attempts to widen and structure the use of the SWOT analysis have been made in the literature. For example, Panagiotou (2003) discusses a 'Telescopic Observation' approach, which provides a logic sequence of dimensions/components to be considered to identify the strengths, weaknesses, opportunities and threats.

An even more formal avenue of research follows the line of using quantitative methods to structure and develop the SWOT analysis. Frequent examples are papers using multicriteria analysis techniques to derive synthesizing judgments. This can take different shapes, each characterized by the multicriteria ranking/synthesizing algorithm used. For example, Wasike at al. (2011) use an Analytical Hierarchy Process (AHP), while Yuksel and Dagdeviren (2007) use an Analytic Network Process (ANP). Along the same lines, Amin et al. (2011) discuss the application of fuzzy logic and fuzzy linear programming to the SWOT analysis.

A closely connected issue is how to build the SWOT based on differing opinions/preferences by different individual experts/groups. This entails, in particular, the progressive systematization and synthesis of the SWOT analysis, e.g. considering the different perspectives of various stakeholders with respect to the SWOT contents and the internal consistency/matching of the related components (Novicevic, 2004). Similarly, Gao and Peng (2011) use a multiple criteria group decision-making technique to account for the uncertain preferences of multiple stakeholders.

Another direction of methodological improvement concerns the use of SWOT information to make strategic decisions. The SWOT framework can be modified to allow for a more direct identification of strength-based strategies through the development of the TOWS framework, in which strengths are directly used to identify strategies to overcome weaknesses, take advantage of opportunities and avoid threats. More quantitative approaches are also available in the literature. For example Lu (2010) uses heuristics (including fuzzy logic heuristics), to study how to proceed from a SWOT analysis to strategic planning in the construction industry.

The SWOT analysis as applied in practice is often subject to criticism, due in part to the frequency of inconsistencies and approximations (Hill and Westbrook, 1997). However, it continues to remain a very popular tool. In addition, despite these drawbacks, its use has widely expanded beyond the initial field of application. In fact, though mostly developed to consider the relationship between an organisation (enterprise) with its environment, the SWOT analysis is now widely used for other objects, including whole sectors, products or policies (e.g. Mili, 2006).

The general result of the recent development towards quantitative approaches is that, by using these methods, the greater level of quantification and formalization also leads to improved internal consistency and more analytical identification of SWOT factors. This in turn helps identify overall messages arising from the analysis. However, it also raises the issue of the trade-off between the simplicity of the SWOT (which is also a key factor in making the method so successful) and the greater structure and rigor that can be contributed by mathematical tools (Lu, 2010).

While the use of the SWOT analysis can easily accommodate considerations concerning different steps in the product chain (i.e. LCA-derived concepts), formal attempts to integrate such concepts, to the best knowledge of the author, are not available in the literature.

3. A Methodological Proposal

3.1 The General Framework

In this paper we propose a framework, entitled LC-SWOT, in which we merge the basic SWOT analysis framework with insights from the LCA. We first outline the general features of the derived methodology and then discuss the content throughout the hypothetical phases of its application.

The LC-SWOT is aimed at providing early evaluation of products or technologies (in the following, for simplicity sake, we refer to products), taking into account the different internal and external factors leading to their success.

In the LC-SWOT method we use: a) the four dimensions of the SWOT (strengths, weaknesses, opportunities, threats) as the dimensions to be evaluated; and b) the material flow of a product "from cradle to grave" as the leading connection throughout the system, taken from the LCA approach.

The general framework can then be conceptualised as in Figure 1.

	Production of raw materials	Processing	Commercialization	Use	Disposal
Strengths					
Weaknesses					
Opportunities					
Threats					

Figure 1. Basic LC-SWOT table

Each box is expected to be filled in with a list of items pertaining to that box. Looking at the table vertically, the four dimensions of the SWOT are analyzed considering the perspective of each stage of the product life cycle. This implies deliberate consideration of the different strengths, weaknesses, opportunities and threats relevant for each step. However, explicitly adopting this framework goes beyond the simple re-classification of SWOT components. This structuring, in fact, raises several issues requiring careful scrutiny.

The tentative procedure to apply this proposed method can be formalised into the following five stages:

1) Formalisation of the objectives of the analysis
2) Definition of the object of analysis and the boundaries of the system
3) Identification of Strengths, Weaknesses, Opportunities, Threats per life cycle stage
4) Synthesis (per dimension/step) and evaluation
5) Contribution to the decision-making process

These proposed steps are discussed in the following with the aim of better explaining and discussing the details of the method.

3.2 Formalisation of the Objectives of the Analysis

The first issue to deal with concerns the underlying objective of the analysis, which means what are the dimensions measuring what the product development is intended to achieve. In a standard SWOT analysis this can be roughly identified as the firm's development. In a standard LCA it is generally the minimization of environmental impacts. In addressing LC-SWOT concepts, this objective can be *per se* ambiguous. One approach could be to focus on the product itself and assess the contents of the four SWOT components keeping in mind an objective consisting of product diffusion (e.g. gaining market share). A second approach would be to take the social welfare perspective, e.g. by pursuing economic, social, environmental sustainability objectives through innovation in a specific sector. In this case, the outcome in terms of evaluation of SWOT components will likely be rather different, as e.g. the greater diffusion of a harmful product can pose a threat for the sustainability of a sector. This is a common issue in bioeconomy-related research, as the involvement of living organisms often produces externalities or impacts the quality of public goods. From the point of view of the method's development, this leads to a distinction between a "product oriented" (when considering private/product development objectives) and a "social-oriented" (when concerned with social objectives) LC-SWOT. However, a socially-oriented LC-SWOT may require a product-oriented LC-SWOT as a first step. As a result, greater clarity in the analysis can be achieved using a two-step procedure: first taking the product perspective to clarify drivers for higher/lower diffusion, then moving to a social perspective to consider S-W-O-T components based on the likely effects on sustainability.

3.3 Definition of the Object of Analysis and the Boundaries of the System

In order to start with the analysis, it is necessary to define what is included or excluded from the system considered and what is the unit of product to which the analysis refers. Issues in the definition of a functional unit and the boundaries of the system are studied in LCA, in which they are well established steps, and the related insights could be adopted for this framework.

This is not a trivial issue, particularly in case of the early evaluation of new products, as the reference "product" or "good" is often not clearly identified (which would occur only at the stage of commercialization or use); this would, in turn, also make partly uncertain the intermediate goods and resources needed to build the reference product. From an economic point of view, this may also require explicit hypotheses to be made about the chain development, which could take different forms, even for the same product, given the state of play of the competitors and the chain actors on the market.

The previous considerations underscore the point that the life cycle of a product does not concern one unique organization (enterprise), but rather can spread across several enterprises. Accordingly, this draws attention to the way in which each step in the product life is organized, and also the relationships between the different steps. In a more contractually-oriented chain analysis, each connection between different steps may in fact become an object of analysis, with related Strengths, Weaknesses, Opportunities, Threats.

A third pivotal issue on this point is the distinction between what is 'internal' and what is 'external' to the system under analysis (i.e. the distinction between strengths and weaknesses, on the one hand, and opportunities and threats, on the other) taking into account that different agents may be inside or outside the product chain. From this point of view at least two options are available. The first is to consider only the product itself as internal. This means, for example, that a strength could be a particular ingredient used to produce a good, but not the efficiency of the firms performing the various steps along the chain. On the contrary, this could be an opportunity. The second approach could be wider and include the firms' characteristics in the system. Hence, the firms' efficiency would be a strength, and the market or regulatory system an opportunity. This distinction leads in fact to distinguish two other variants: a "product-oriented LC-SWOT" analysis and a "chain-oriented LC-SWOT" analysis. The former approach may appear as simpler and more consistent with the aims of the analysis, and, from a practical point of view, likely more suitable when the chain is still unstructured or uncertain from the point of view of the economic agents involved.

3.4 Identification of Strengths, Weaknesses, Opportunities, Threats per Life Cycle Stage

This is the core of the method, in which the different SWOT components are identified and enumerated. A practical issue for this stage remains where to obtain the know-how necessary to fill in the matrix and which practical method to use to gather and elaborate such know-how.

Developing from the SWOT perspective, qualitative expert-based methods are the obvious candidates for the analysis. Structuring SWOT dimensions through the product chain would require making explicit the need for different expertise and the need for the various expertises to establish a dialogue around the same system. Participatory techniques, such as expert meetings could be the most appropriate candidate methods for light LC-SWOT. A more structured analysis could require Delphi techniques, allowing to proceed in different steps, and, for the experts, to collect documentation during the process. There is also a tradition in using these methods for *ex-ante* technology evaluation.

Given the potential social concern or public good issue behind the products under analysis, a wider set of concerned stakeholders could be involved in this stage. For many products in which markets are still to be developed at the time of the evaluation, market information (retailer and consumer views) need to be incorporated in the process. However, the consumer's ability to provide a preference for products that are not yet familiar can be limited and require a cautious evaluation. Generally speaking, in most innovative bioeconomy sectors, demand needs to be created at the same time supply is being developed, leading to the need to consider the entire process of market establishment for a new product.

The connection between qualitative/expert and hard data can also be considered. The LC-SWOT perspective allows consistency with the LCA in the structure of the system considered and this offers an opportunity to use the two sources of information together. The connection can be made both upstream (i.e. the LC-SWOT can provide a qualitative exploration of issues and a structuring of the system to be addressed in an LCA) or downstream (i.e. the LC-SWOT can provide a qualitative assessment of the overall ability of the innovation to work using the quantitative analysis provided by the LCA as an input).

An important opportunity provided by the LC-SWOT perspective as compared to the SWOT, is the possibility to address explicitly the interplay between different stages of the chain, including: a) the common/different determinants of outcomes in different stages; b) the causal connection between (different or potentially opposite) evaluations in different stages, e.g. shifting the burdens created by negative effects from one stage to another of the chain ; and c) the bottlenecks or critical points in the chain from an economic/social perspective.

3.5 Synthesis (per Dimension/Step) and Evaluation

This stage would enable to provide an overall judgment about the outcome of the SWOT. "Aggregation" could be made either by stage of the chain or S.W.O.T dimension, i.e. horizontally or vertically in the framework provided in Figure 1. This is important as it allows for the drawing of intermediate insights about the composition of the effects and their overall evaluation. "Aggregation" may also mean focusing attention on the most relevant points. For example, identifying the comparative importance of bottlenecks would be an interesting option in order to exploit the potentialities of using a LC perspective coupled with a SWOT analysis.

A comparison of different products/chains is also possible. A noteworthy point concerns the fact that a good deal of environmental evaluation tools, including LCA, are used in a comparative manner, i.e. to compare product performance. This is not usual for the SWOT approach. In fact, the SWOT usually incorporates an implicit comparison component, as long as the identification of strengths and weaknesses entails a comparison with competitors. In the use envisaged for the LC-SWOT, however, this comparison could become explicit, hence requiring a more systematic assessment, possibly using checklists etc., of potential strengths and weaknesses.

Finally, the SWOT analysis is basically a qualitative technique. However, formal comparison of alternative product chain perspectives may require, or at least benefit from, the use of quantitative techniques, possibly from the field of multicriteria analysis. This is a tendency already seen in both LCA and SWOT, and would be a suitable direction also for LC-SWOT, particularly thanks to the more structured format.

3.6 Contribution to the Decision-Making Process

A fifth issue concerns the relationship between the evaluation exercise and decision-making. While the SWOT approach is mainly oriented towards evaluating potentialities to support strategic decision-making, LCA relates more to predicting environmental effects. When merging the two concepts, the contrast between potentialities and predictive use may become more evident and require clarification. A major issue, in this respect, is the fact that potentialities at one stage of the chain can become actual only depending on which potentialities become actual in another stage. This may lead to actual opportunities and threats, or, more realistically, the need for the explicit identification of the interconnections between the different components of each step. This problem is largely unaddressed in the value chain approach as this concept is more frequently used *ex-post* on observed data, hence building on the observed, rather than on the potential chain structure. Yet the very challenge of our proposal is to deal with the *ex-ante* analysis of products. This, by definition, entails analysing production chains that are still unstructured and markets that are yet to be developed. In addition, contrary to the SWOT perspective, decisions at this stage are not concentrated in one decision-making unit, but rather are spread across different actors in the chain (which, on the other hand, is also the case for the effects of the new product).

That said, this stage can also go beyond the generic accounting of the decision-making process and expand to more decision-supporting content, such as using the LC-SWOT results to build a LC-TOWS matrix, with, in addition, the possibility of discussing the strategy's consistency across different steps of the chain.

4. Extensions

The simple proposal developed in the previous section can be used to raise ideas for further development. We discuss this in relation to three potential extensions: a) using a different (marketing) concept of life cycle; b) using a technology rather than a product as the object of analysis; c) expanding further the life stages to connected components upstream and downstream.

Concerning point a) we have up to now, and consistently with the LCA literature, considered the life cycle of products as the different steps of product manufacturing and use. Yet in economics the term 'life cycle' can also be used to define the life of a product over time. This is typical in the field of marketing. Over time, a product is launched, develops a market, experiences a maturity period and then declines. The indicator representing such a process is generally the evolution of the product's turnover over time. An option is then to use this marketing concept of life cycle instead of the product life cycle in the LC-SWOT, or, alternatively, to add a third dimension to Figure 1 representing the product life cycle in the way in which it is used in marketing. This idea can be more or less relevant depending on the expectations regarding the changes in SWOT components over the time of the product life cycle.

A second point (b) is that of using a technology rather than a product as the object of analysis. This may be particularly important for research projects, where technologies, rather than products, are often developed. In this case, the option of using the life cycle over time as the reference stages of the SWOT analysis become more important, as a technology can have a given life span, with different good and bad components generated over time, in relation to substitutes.

Point three (c) concerns the expansion of the life cycle to "connected activities". This may occur upstream, e.g. concerning research activities to develop a product or a technology, or downstream, e.g. with respect to the support for the development of new technologies. These kinds of expansions may apply, though in somewhat different ways, for both the standard LCA life cycle and for the marketing life cycle concepts.

The case for upstream analysis relates to the need to account specifically for technology and knowledge building as a potential area of societal concern. This relates explicitly to recognizing the relevance of potential spill-overs, and the development of new child technologies etc., which are sometimes more important than the technology being evaluated itself. On the other hand, it is also necessary to recognize that in the debate concerning bioeconomy technologies (e.g. GMOs), knowledge (basic research) itself has rapidly become non-neutral, at least in terms of opportunities and threats, and hence the stage of knowledge production should be properly considered in this framework.

In analogy, downstream effects such as the induced modification of the product chains, displacement of alternative product/technology chains, equity concerns, launch/support of new socially sensitive activities are potentially relevant effects to be considered in product/technology evaluations in the bioeconomy.

It is very likely that any sensible SWOT would consider these issues whenever relevant. However, the explicit specification of stages in the life cycle to be referred to in the selection of S.W.O.T components may at least help in avoiding confusion and omissions.

5. Discussion and Conclusions

The development of new technologies in the field of food production, and the bioeconomy in general, has raised society concern and lead to major conflicts, sometimes at the expense of technology development. The strong emphasis now placed on innovation by EU public institutions needs to overcome such limitations in order to bring about the expected social benefits. This can benefit from improved evaluation support means.

A challenge in this regard is the increased complexity of the technologies and the context in which they are developed. In particular, the concept of the bioeconomy encourages on its own more and more interconnections in the material flows across sectors and geographical areas. It also encourages the application of innovative technologies in the field of biological resources, which raises a wide range of potential evaluation concerns.

Reactions to this demand for evaluation instruments are addressed in the literature. Technical literature progresses to more detailed and structured recording of effects, like in LCA. Management literature, for its part, is moving toward an increasing use of qualitative/expert-based instruments, to capture complex relationships.

The literature concerning these tools seems to demonstrate, in both cases, an evolution towards the other. LCA methods are becoming stronger in the evaluation step, in order to contribute to strategic decision-making. Qualitative strategic decision tools, such as SWOT, are moving towards more structured approaches, in particular by taking into account the different strategic dimensions to be considered and the technical components of the products being analysed. Both fields apply more and more often quantitative means, supporting a more rigorous evaluation of products/technologies and making explicit the view of different stakeholders in the evaluation process.

In this paper we develop the proposal for a LC-SWOT approach which synthesises these trends and is potentially able to address some of the challenges inherent in the evaluation process. The arguments introduced in this paper and the methodological proposal developed propose an evolution of the classic SWOT analysis and indeed suggest the integration of the LCA concept as a potentially fortuitous avenue for the development of suitable tools for the early evaluation of technologies/products in the bioeconomy. Though we do not provide empirical application, the relevance of this issue is highlighted by the fact that structuring and interpreting the components of the SWOT is not a trivial process, and will benefit from more formalized approaches.

The number of alternatives and issues raised by the joint use of the SWOT and LCA concepts also point to the need for a formalization of the alternative configurations of the method, and the identification of assumptions and criteria to be used in the different steps of application, in order to ensure that exercises concerning different product alternatives are indeed comparable (when they need to be).

Moreover, alternative uses may be envisaged, in particular by distinguishing the option of using the LC-SWOT as an independent tool from its potential use as a support/complement to the LCA, or to synthesize the outcome of wider economic and environmental assessments.

Besides the consistency with the LCA, an encouraging observation is that the value chain, following the product life cycle through the interconnected enterprises leading to some product, is a widely used approach in modern chain management, particularly, but not only, in the food sector (Porter, 1985). The study of the connection between the two methods can therefore also suggest new opportunities for a dialogue between environmental evaluation and strategic business analysis in emerging markets.

While this paper contains a methodological proposal, the method is still to be tested in practice. This constitutes an opportunity for further research in this field, and one that will also allow for further refinement and empirical assessment of the method. Experience with the history of the SWOT analysis shows that even such apparently simple techniques can benefit a great deal from structuring and consistency checks. Given the problems addressed in the evaluation of new bio-based products and technologies, the ability to use a relatively cheap but powerful tool, whilst guaranteeing the quality of information produced can be of significant assistance in ensuring a cost-effective analysis of new technologies and hence an ultimately smoother innovation process.

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