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Bringing the local back in. The role of territories in the "biological" transition process toward circular economy: A perspective of analysis

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As widely evidenced in the past decades, the level of "humanity's metabolism" is unsustainable and must be reduced. It is especially related to issues, such as availability of resources, impacts of transportation, waste management, and external costs that could adversely affect the economic and environmental scenario at a global level. In the transition to circular economy (CE), moving from the insights of industrial ecology (IE) and the related "biological paradigm", it has been suggested that the *meso* scale is the one in which great efficiencies can be achieved; the focus is on territories in which networks of economic actors' express significant potential in terms of synergistic and efficient use of resources and wastes. This *perspective article* aims to propose a detailed methodological viewpoint of this issue, moving from the scientific and empirical experience gained in a long-term research project conducted by the author on the themes of IE, CE, and their development in local contexts. The first phase of the research was characterized by theoretical-methodological in-depth analysis, case studies, and pilot tests, including different operating local contexts to evaluate their potential for the development of IE-based approaches. The results obtained and the experiences gained in the first phase have been used to develop an interpretative framework for assessing the role of external factors in influencing the process of development. Currently, the research is aimed at developing an analytical model capable of representing both the structural and operational characteristics of such contexts and the relative factors of influence in view of the adoption of circular strategies for the territory in which they are located.

KEYWORDS

circular economy, territories, industrial ecology, biological paradigm, industrial symbiosis, urban metabolism, analytical model

Introduction

Never as in this historical period, the expression "*Think globally, act locally*", one of the most famous slogans of the '70s environmental movement, returns to relevance in the profound processes of change that society as a whole is witnessing and is called, in one way or another, to face, showing a sense of responsibility that is both individual

and collective. Concepts such as *adaptation*, *resilience*, *antifragility*, and *resistance* have become increasingly current, as a result of extreme events and are further accentuated by old and never resolved issues of inequality, but also of dependence on resources and, more generally, on the natural environment. Above all, because these types of events, which initially appear relatively isolated, often spread rapidly on a global level. In such a changing and unpredictable context, economic systems are subjected to a major restructuring that pushes toward greater sustainability. Recently, global efforts driving toward more sustainable production and consumption models have resulted in the affirmation of the circular economy (CE) paradigm. CE entails a systemic transformation of whole economic systems, at various scales, covering production, use/consumption, and end-of-life phases, so that the value of material and energy flows can be maintained in the technosphere as long as possible (decoupling effect), while reducing environmental impacts in terms of resource depletion and pollution (Kirchherr et al., 2017).

It is well-known that paradigmatic jumps require an adaptation of the system from both a structural-morphological (e.g., roles and technologies) and functional-operational side (e.g., rules and routines), from the various actors involved, which in this case are different economic agents that operate according to economic rules. The speed with which CE is spreading raises some concerns on systems' ability to metabolize and implement these changes in an effective way. If these gaps are physiological in a pre-paradigmatic phase, in which actor's behaviors are not aligned (but rather are typically divergent and unpredictable), over time, some solutions will prove to be more effective than others and will establish themselves as technological, production, consumption standards, to define the effective achievement of a "circular economy era". However, on a global scale, there is a persistent problem related to operational complexity and inevitable geographical disparities, difficulties in supply chain traceability, and control and impacts related to transportation activities, which make fully circular principles and models less applicable. Moreover, to date, studies and good practices of CE often seem to have a spatial disconnection that severely limits their development potential on a large scale.

Local territories seem to have the potential to support the triggering of circularity processes (Bourdin et al., 2021; Tapia et al., 2021), in particular, those socio-economic settlements with blurred borders, characterized by potential trajectories of expansion, upstream and downstream, which include multiple dimensions. This also applies to those territories that cannot count on the availability of virgin resources and raw materials and that can instead promote recovery paths based on the exploitation of circular options (e.g., reuse, remanufacturing, recycling, and energy recovery).

This *perspective article* aims to contribute to such debate, proposing a detailed viewpoint deriving from the scientific and empirical experience gained in long-term research conducted by the author on the themes of IE, CE, and the development of these approaches in local contexts. In particular, the main characteristics and potential of these contexts, the factors that influence the development of CE and IE approaches, and the limits still existing for their practical implementation will be highlighted, finally proposing an analytical model, currently under development, that can help fill these gaps.

Back to the territory

The early 1990s marked a period of sweeping geopolitical changes, dominated by historical events, such as the end of Cold War, the collapse of Soviet Union and Berlin Wall, and the expulsion of Iraqi military forces from Kuwait. These events caused the end not only of the East-West political-ideological conflict but also of the economic one between Western-style capitalism and the planned economy of the communist regimes (Diener and Hagen, 2009). As a response, at that time, the concept of "globalization" took hold, which imposed itself as a world economic paradigm, of a world without borders.

The advent of the globalization era led to, among other things, the removal of restrictions, duties, and customs barriers for the mobility of people and goods, the fragmentation of supply chains, through outsourcing and relocation of production activities, and logistics integration. It established itself as "*spatial-temporal processes operating on a global scale that rapidly cut across national boundaries, drawing more and more of the world into webs of interconnection, integrating and stretching cultures and communities across space and time, and compressing our spatial and temporal horizons*" (Inda and Rosaldo, 2006). The speed of the changes generated by the globalization process that literally overwhelmed the whole world did not allow, for example, to understand (nor to foresee) the speed with which adverse events could also have been spread from one point of the globe to another and also the extent of "rebound" effects that they could have generated and which is threatening the economic sustainability of many businesses (this is particularly true for raw materials and natural resources). An initial enthusiasm to literally step outside of one's own borders, real and virtual, which globalization made possible, a phase of stabilization in which, almost in parallel, the local trajectories also went redrawing, has followed. What we are witnessing today is a very particular time for the dynamics of the world economy which, on the one hand, highlights the damage caused by the excesses of ungoverned financialization and globalization and, on the other hand, brings to the fore the importance of the real economy, which finds its highest expression in local territories.

The word territory derives from the Latin "*terrae torus*", which literally means "*bed made of land*", and it originally designated the land that ancient peoples took possession of and delimited. As recognized in the literature, the concept of territory has evolved in many ways over the centuries and has

attracted the interest of geographers, politicians, economists, sociologists, and jurists (Gottmann, 1973). Despite the fact that in recent decades there has been a gradual removal from territories, they are now regaining increasing importance in world development policies due to their capability of repopulating the abstract space of a globalized world through their own values of specificity and differences. In this view, local territories can play an important role on the human level, by building human relationships and cultural and social dynamics; on the economic level, by enabling a network of actors working together, and by serving as a wellspring for innovation and economic dynamism; on the political level, by highlighting the importance of relations between civil society and local authorities, and by serving as the building block for strong democratic governance; on the ecological level, by a proper and circular managing of material and energy flows.

The role of territories in the CE paradigm: A perspective of analysis

Premise

Current economic models are not able to predict when the CE era will actually happen; I presume numerous decades and human generations. What is likely to be possible at this stage, by those involved in research, is to lay the scientific and methodological foundations so that the transition takes place in a more technically, economically, and socially balanced way. To this end, defining models for possible solutions (technological, organizational, and managerial) will need to be implemented; methods, metrics, and measurement tools will also have to be adopted as well as effective communication and dissemination tools. Most of that, in the transition toward CE, is currently missing, because, as mentioned, the overall picture is so complex that it would be practically impossible to hypothesize that all the possible aspects could be enclosed in a large-scale single model, and in a balanced functional relationship. This can be considered a general scientific macro-gap, which must be faced and bridged, or, at least, broken down to be approached effectively.

Inspiration: The biological paradigm of industrial ecology

Recent studies propose hypotheses and approaches for the analysis of socio-economic systems characterized by a simple, elegant, and extraordinarily effective inspiration: the biological systems. These studies, grouped under the "Industrial Ecology" concept (Graedel, 1996), were definitively established at a global level in the late 1980s and proposed a new concept in which a socio-technical system is viewed not in isolation from its surroundings but in concert with them. IE seeks to optimize the total materials cycle from virgin material to finished product and to ultimate disposal moving from the metaphor of the natural ecosystem, which starts from the assumption that in the natural world no waste is produced; waste is essentially a social or human construct (Jelinski et al., 1992). In this kind of system, the concept of waste is practically lost in favor of a cyclical vision of flows, whose technical and economic value is maintained within the system, (almost) decoupling them for quite a long period of time from their reference biological system. For these reasons, IE can be recognized to all intents and purposes, as the scientific basis of CE and its methodological approaches and tools can effectively be used to guide change toward CE. In particular, the so-called "Place-based" approaches to IE promote more sustainable paths of local development or redevelopment through innovative methods, tools, and applied solutions able to improve the socio-economic and environmental performances of local territories (Deutz and Gibbs, 2008; Simboli et al., 2012).

Understanding the potential of territories the interpretative framework

Earlier studies conducted by the author in operating local contexts, such as industrial clusters, districts, business networks, and urban areas, are used here as a foundation of the perspective analysis (Taddeo et al., 2012, 2017a,b; Simboli et al., 2014, 2015, 2019). During the multi-year study, desk analysis research (aimed at carrying out literature reviews) and on-site research (aimed at developing case studies) have alternated. In the on-site research, mixed methods have been used: quantitative for the analysis of the technical aspects of the solutions identified (using data from local databases and questionnaires administered) and qualitative for the other aspects investigated (using data from focus groups and meetings). The questionnaires were developed with reference to the scheme drawn up by Heeres et al. (2004). The role of the researchers was active as regards the collection of data and as participant observers for the others. Both qualitative and quantitative data obtained were used to set the framework and the analytical model presented hereafter.

The studies highlighted that a number of significant factors influencing the development of IE-based solutions (mainly inspired by Industrial Symbiosis—IS) in an existing local context may derive from different stages of its life-cycle. The relations between the evolutionary dynamics of existing contexts and the development of IE-based solutions as the most relevant (Jacobsen and Anderberg, 2004) have been considered. The empirical evidence pointed out the role of non-technical factors, often defined as "embedded" in the context (Costa and Ferrão, 2010; Doménech and Davies, 2011; Schiller et al., 2014).

An interpretative framework (Figure 1) was, therefore, created to include these categories of factors, that refer to, respectively the *current state of the context*: factors contingent

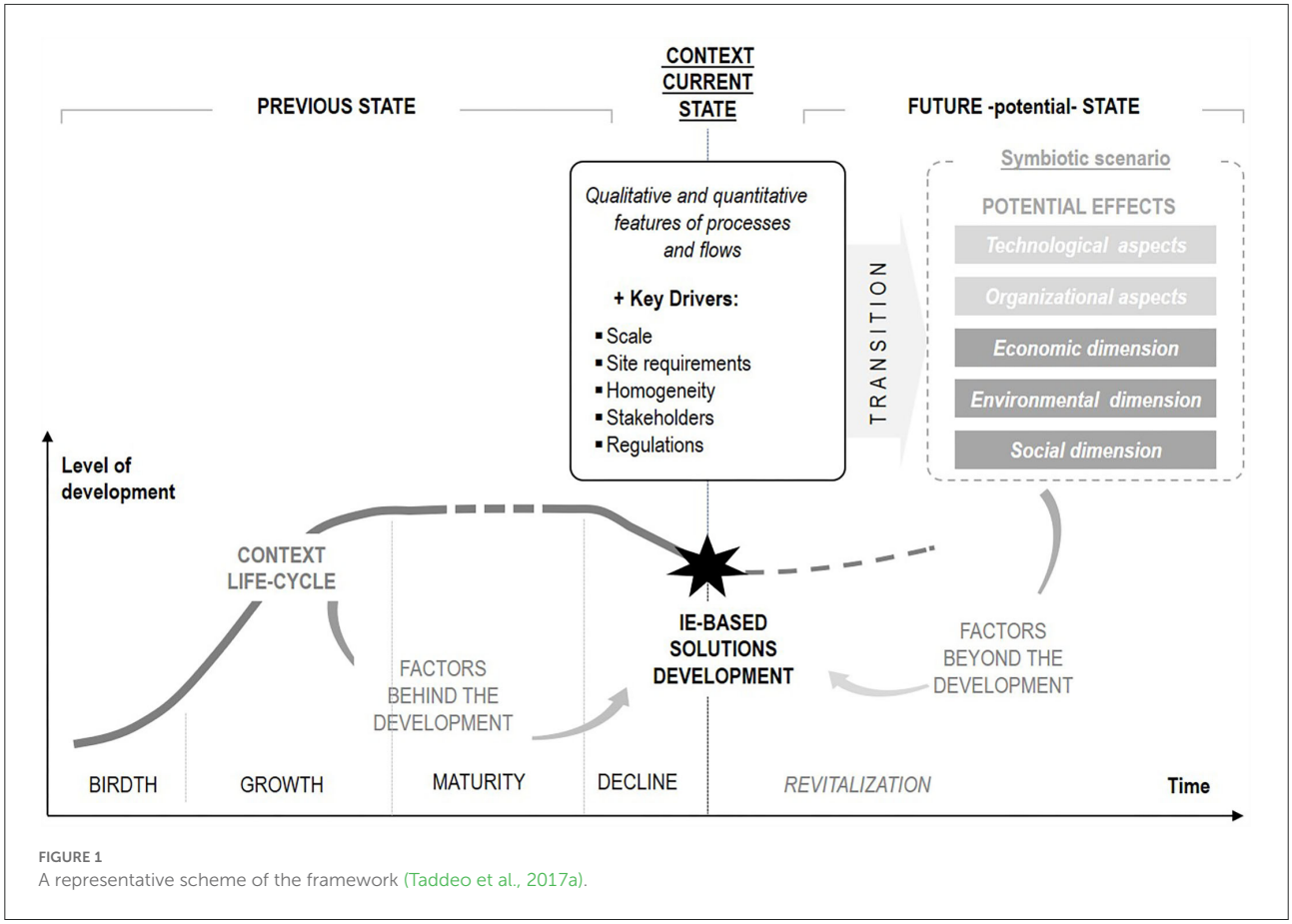

FIGURE 1
A representative scheme of the framework (Taddeo et al., 2017a).

to the development of the IS (e.g., the scale of the site, the level of homogeneity of the industries involved, the presence of infrastructures, the current regulations, the active participation of stakeholders in providing data, and organizational support); *previous state of the context*: factors behind the development of the IS (e.g., culture, experiences, knowledge, roles, and operating rules and routines); and *future potential state of the context*: factors beyond the development of the IS (e.g., the perception of the local stakeholders on future effects/potential benefits of the IS).

The contexts analyzed have shown a good intrinsic potential to embrace IE-based solutions, both technically, economically, and environmentally and this can be considered an element in the favor of a "local" circular transition. Other elements that emerged clearly are the complexity of these contexts and the diversity that they can demonstrate, even though they belong to the same geographical areas.

Some methodological gaps in managing the transition also emerged. In this sense, the first limitation is linked to the fact that the main current analytic approaches are static. There was no prospective vision—evolutionary and dynamic—with which to define paths of development for the contexts analyzed. A second important limitation is related to the possibility of measuring and communicating the economic, environmental, and social effects of these initiatives. Most of the current approaches (e.g., those life cycle based, such as Life Cycle Assessment and Organizational Life Cycle Assessment) operate according to a reference flow and show limits if their use is extended to contexts that have a spatial extension (the same is for the availability of data or the definition of the functional unit or the allocation rules).

Representing the evolution of local contexts: The analytical model

The second part of the research, starting from the inspiration of the biological paradigm of IE and the results obtained by previous research was devoted to partially fill the methodological gaps above presented. The general problem to be dealt with was: how can the transition process be supported and made more effective? The technical elements deemed essential to answer this question were: the knowledge of the features of the contexts and of the influencing variables (internal and external); the presence of potential solutions applicable

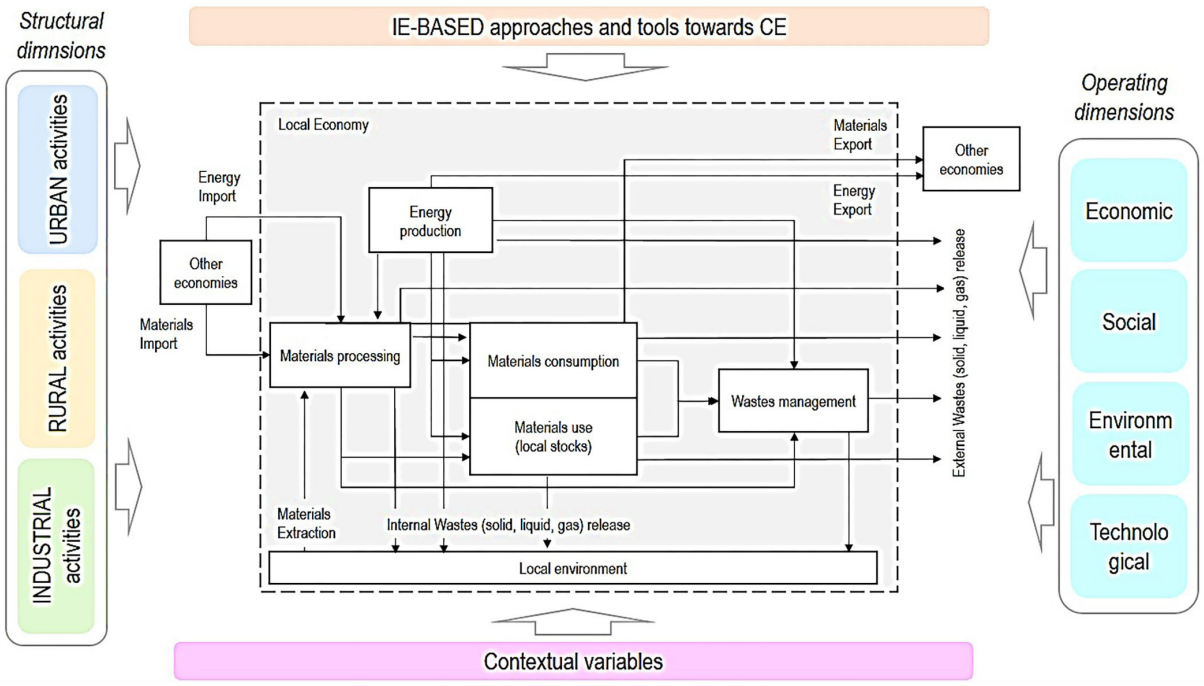

FIGURE 2
A general scheme of the dimensions and the variables included in the analytical model.

(IE-based) and suitable for the context; and the role of support tools.

It was believed that an *integrated and multi-dimensional analytical model* (that integrates these aspects) could contribute to the advancement of knowledge and the reduction of the complexity associated with the adoption/diffusion of CE practices at a local level. Figure 2 depicts a general scheme of the model, highlighting actors involved, type of activities, structural and operating dimensions of the system, material and energy flows involved, potential IE-based solutions, and external factors.

In the internal gray area, the actors/entities operating in each context have been represented as general anthropogenic activities (e.g., production, use, and consumption activities) by input-output schemes able to outline their functional characteristics and the potential (physical) relationships with other entities.

Around the system, the representative elements of the analytical model proposed are reported.

The three contextual dimensions considered for characterizing the hybrid systems were: industrial (that offers the presence of large volumes of material and energy flows that are used and discarded); urban (that offers the possibility to develop a powerful integrated approach for understanding "urban metabolism" in relation to "industrial metabolism); and agro-rural (the presence of agro-rural activities offers the potential to increase the efficiency in the local use of resources for CE purposes). For each of the three structural dimensions, operating dimensions have been considered: (i) the *techno-economic* dimension includes the features (technology, organization, and processes) and the typical behavior (strategies) of the actors involved in local contexts, (ii) the *socio-relational* dimension includes all those variables related to the ways and forms of interaction among actors (companies, local authorities, etc.), and (iii) the *environmental* dimension includes the analysis of all the flows that have an impact on the environment (consumption of resources, emissions into air, water, and soil) and their determinants (primary processes, industrial transformation, use, and end of life).

The IE-based techniques, tools, and influencing factors that are appropriate for the settings are also highlighted in the external area.

The model, once made operational, provides that the adoption of IE-based solutions will redefine the roles and the relations (social and physical) among the actors, making them capable of establishing a new trajectory of development, toward CE (potential closed-loop scenarios), taking into account the effects of external variables and their potential effects. It is believed that the use of this type of methodological tool can help the subjects directly or indirectly involved in the transition process to visualize the context, the elements involved, and

the evolutionary potential and therefore to make the most appropriate decisions.

Discussion

Even back in 2006, Boons and Baas (2006) discussing IE-based activities, stated that these *are shaped by the context in which they occur, described in terms of cognitive, structural, cultural, political, spatial, and temporal embeddedness*. The present *perspective article* highlighted the strategic role that local contexts can play in the transition process toward CE, the methodological gaps in managing the transition and the elements and variables involved in the process, proposing an analytical model to reduce such complexity.

Even if CE practices are proliferating internationally, there are still many theoretical, methodological, and applicative issues that need to be faced and solved, otherwise, there is the risk that they will remain sectoral attempts, isolated in time and space. The growing competitiveness within the national and international markets along with the current supply issues, is forcing companies to identify new sources of competitive advantages and new business models, also deriving from actions involving local contexts and territories. In rekindling attention on the role of territories and local contexts, what is still missing are integrated tools for the analysis, modeling, and representation of CE scenarios applied to these contexts, which could instead highlight the real development potential and support decisions. To overcome this limit, there is a need to identify and analyze the main variables and the factors of influence. In this perspective, the proposed research aims to provide a framework of analysis and a better characterization of local contexts to govern their transition toward more sustainable models. The research final output may provide the involved entities (public and private) with a model capable of identifying new ways for improving local competitiveness and sustainability, while also encouraging eco-innovation and cooperation and making a better use of energy and material resources. The expected results may also contribute to reinforce the local knowledge and technological basis to define new sustainable growth strategies. The use of an integrated model will also allow us to transfer and replicate the acquired know-how in other territories and take advantage in terms of collection and analysis of data and internal and external communication. Despite some identifiable limitations in the complexity of systems analyzed and the availability of updated data, the use of such models can help in promoting the empirical applications of design, measurement, management, and forecasting models for the development of CE at the territorial level.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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