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Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research

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ABSTRACT

The intermeshing of disciplines from the natural sciences, social sciences, engineering and management has become essential to addressing today's environmental challenges. Yet, this can be a daunting task because experts from different disciplines may conceptualize the problems in very different ways and use vocabularies that may not be well understood by one another. This paper explores three alternative environmental concepts used in transdisciplinary research, and outlines some of the epistemological and practical problems that each one poses. It pays particular attention to the increasingly popular concept of "circular economy", and contrasts it with the more commonly-used concepts of "environmental sciences" and "sustainable development". In clarifying the nature, meaning and inter-relationship of these alternative concepts, the paper helps trans-disciplinary researchers to understand the opportunities and challenges associated with each one.

We live in a world with rapid anthropogenic environmental changes. The challenges associated with this make it essential to bring together various disciplines so that we have a detailed and integrated picture of our current predicament as well as the capability to avoid, reduce or mitigate the problems that arise. Many concepts, along with their different vocabularies, have been used to enable this intermeshing of disciplines. Two of the most common are "environmental sciences" and "sustainable development". More recently, "circular economy" has come into currency. While all of these concepts are different, they share two important factors. First, all of them have an over-arching objective of addressing environmental problems. Second, the study of these rely – to some extent – on trans-disciplinary research.

In this communication, we identify some of the challenges and opportunities that are associated with each concept (epistemological and practical) that can either help or hinder inter-disciplinary efforts to address environmental challenges. Our specific objectives are to clarify and contrast the underlying premises of each concept, and to identify how they can be applied as a means of addressing contemporary environmental challenges. Although the purpose of the paper is to highlight the differences in the understanding, by various disciplines, of key terms linked to the environment, we do not cover all the disciplines or all the different interpretations.

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Table 1
Alternative environmental concepts in trans-disciplinary research.

	Definition	Core concept	Anthropocentric	Ecological objectives	Economic objectives	Social objectives	Internalization of environmental impacts	The application depends on some authority
Concepts based on the natural environment								
Environment	All the natural components of the Earth (air, water, soils, vegetation, animals, etc.) along with all the processes that occur within and among these components	System essential to and impacted by human activities	No	No	No	No	N/A	N/A
Environmental protection	Search for minimizing or reducing environmental impacts	Societal objective	No	Yes	No	No	Yes	Yes
Environmental sciences	Sciences that study the environment (and, in particular cases, solutions for its protection)	A set of scientific disciplines	No	No (Yes)	No	No	N/A (Yes)	N/A (Yes)
Concepts based on inter-generational sustainability								
Sustainable development	Meeting the needs of the present without compromising the ability of future generations to meet their own needs	Societal objective	Yes	Yes	Yes	Yes	Yes	Yes
Concepts based on the models of economic production and consumption								
Circular economy	Production and consumption of goods through closed loop material flows that internalize environmental externalities linked to virgin resource extraction and the generation of waste (including pollution)	Model of production and consumption	Yes	Yes	Yes	No	Yes	Yes
Linear economy	By opposition to the circular economy, production and consumption of goods that (partially) ignore environmental externalities linked to virgin resource extraction and the generation of waste and pollution	Model of production and exchange	Yes	No (Yes)	Yes	No (Yes)	No (Yes)	No (Yes)

1. Multi-, pluri-, inter-, trans- disciplinary research: some challenges and benefits

Interdisciplinarity, multidisciplinarity and pluridisciplinarity occur when two or more scientific disciplines work together to pursue a given project, with the contributions from the various disciplines being essential to revealing and addressing the different aspects of the problem. Each form is different, related in large part to the degree of interactivity among disciplines. Among the different forms of interdisciplinary meshing, transdisciplinarity is perhaps the easiest to distinguish. Transdisciplinarity only applies when disciplines must mesh together to fully identify, construct, grasp and comprehend a specific object of inquiry. It requires a perspective that goes beyond individual scientific disciplines and even the subject of the research, so as to better grasp its scope and consequences. As such, transdisciplinarity does not recognize any boundaries to the problem studied and promotes a holistic approach.

Our objective is not to try to differentiate the degree of meshing among the disciplines and to make judgements as to whether a specific issue should be referred to as inter, multi- or pluri- disciplinary. Rather, our concern is that meeting today's environmental challenges almost always has some level of intermeshing of disciplines (Kajikawa et al., 2014). The difficulty of distinguishing the form of intermeshing in no way takes away from the recognition that incorporating the perspectives of different disciplines is important. Current investigations show increasing trends towards the integration of more interdisciplinarity within sustainability research (Schoolman et al., 2012). Furthermore, it is critical to accept that only the experts from different disciplines are actually able to ascertain whether their disciplines are pertinent for a specific investigation.

We do note, however, that challenge of intermeshing different disciplines grows with the degree to which they differ from one another in scientific approaches, expert training, and desired objectives. One could argue, for example, that a chemist trained in the synthesis of organic chemicals could work, with relative ease, in a multi/inter/pluri/disciplinary way with an analytical chemist to tackle atmospheric pollutants. However, the distance in approach and thinking increases if we have to combine our chemist with an engineer to improve the performance of a wastewater treatment plant. It is certainly easier to combine different fundamental scientific disciplines that are in the same broad family (fundamental physical sciences, for example if we combine chemistry, physics and engineering) than when they are not.

The most daunting transdisciplinary challenges arise when the vastly different approaches from physical and social sciences need to be combined, for example, in studying the remediation plan of a contaminated urban area. In this situation, you need to combine expertise in soil remediation, chemical speciation of the contaminants, environmental fate, human health effects, eco-toxicological impacts, socioeconomic perspectives, urban planning, and so on. The wide range of specialists who are needed to do this will not share the same training and perspective to address the same issues, nor will they perceive or even define the problem from the same angles or focus on the same subsets of milestones and potential solutions.

One of the specific problems that arises when experts from different fields work together is that they may use the same words and labels for their efforts – but have very different understandings of their meanings (Loewenstein et al., 2012). Their discussions can become a "dialogue of the deaf", with confusion, poor coordination, and ineffective collaboration. A common vocabulary – with shared meanings – is essential to enable an effective intermeshing of disciplines. A vocabulary is a "system of words and their meanings commonly used by social collectives" (Mebratu, 1998). Vocabularies are consequential for cognition – i.e. how a subject is framed – as well as for coordination – i.e. how people work together towards common goals.

In the rest of this article, we explore three concepts – "environmental sciences", "sustainable development" and "circular economy" that have come into use to express scientific concerns and efforts to protect the environment. Our focus on these three concepts is guided by their prevalence in tackling environmental challenges as well as the transdisciplinary nature of each one. In the following sections, we outline and contrast the underlying premises of these concepts. We pay particular attention to the vocabulary associated with each concept and examine how there can be substantially different meanings that can influence the effectiveness of transdisciplinary efforts to develop a detailed, integrated assessment of the situation and the means to address it. In Table 1, we summarize the concepts and six of their underlying premises related to their anthropomorphism, the inclusion of ecological, social and/or economic objectives, the extent to which environmental impacts are internalized, and the necessity for intervention by a public authority. We develop this further below.

2. Two common concepts: environmental sciences and sustainable development

We first examine and contrast two of the common concepts used to articulate and frame scientific efforts to protect the environment – namely "environmental sciences" (which can incorporate both "environment" and various applications in environmental sciences) and "sustainable development". Both are common concepts used to articulate and frame scientific efforts to protect the environment. While it is clear (as we show in Table 1 and as we outline later) that these two concepts are not synonymous – particularly in terms of the scope of their objectives – they also hold the potential to come into conflict with one another, depending on how the terms are used and understood.

The problem starts with the definition of "environment". Very simply, "environment" can be defined as the biological and abiotic elements surrounding an individual organism or a species, including many of which contribute to its wellbeing. "Environment" can also be defined as all the natural components of the Earth (air, water, soils, vegetation, animals, etc.)

along with all the processes that occur within and among these components. As such, the boundaries of the "environment" are best defined by the focus of the question, they will change according to the problem at hand but in a broad sense, no environmental issues should fall outside the field of "environment".

When applied to environmental sciences, "environment" is often associated with "environmental protection", which can be defined broadly as efforts to both understand the mechanisms at play within the environment and the solutions (technological or other) that can have some impact (positive or negative). Environmental sciences existed long before society at large had environmental concerns. Such sciences study (and continue to study) the environment whether they are degrading or not. The role of environmental sciences took a turn with the realization that human-induced stresses on various environments were taking a dangerous toll: some types of human activities were understood as not being sustainable. This is when the shift to "sustainable development" occurred (Mebratu, 1998). The often-quoted Brundtland report defined sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*" (World Commission on Environment and Development, 1987).

While "environmental sciences" (along with the implied meaning of "environmental protection") and "sustainable development" have obvious linkages, they are not synonyms. Many issues may fit with both environmental science and protection and with sustainable development. However, in some situations – and with some research questions – it can be harder to see the links between the two. These gaps become particularly apparent in reflecting on the role played by humans and their impacts on the environment.

One of the key areas where these two concepts diverge is related to the role of humans and their impact on the environment. Sustainable development takes an anthropocentric perspective: it is implicitly about current and future generations of *humans*. As such, it cannot be considered congruent with environmental sciences. Although researchers in sustainable development acknowledge the value of the environment on its own, they generally consider the environment as an essential part of a broader system that fulfills human needs and desires. Knowing how current human activities dynamically affect tomorrow's environment is a key focus of study. In this perspective, sustainable development is the end goal, and environmental protection is a subsidiary goal. It is important to note that some of the social issues and objectives embedded within the sustainable development concept – such as the promotion of human rights – have few direct links with environmental issues. The potential for confusion is certainly present (Bartelmus, 2013) and further exacerbated because in many disciplines, sustainable development is a sub-area of environmental sciences rather than the other way around. Many environmental experts focus their work on understanding environmental issues with little or no research focus on (human) development of any kind.

3. Environmental sciences and sustainable development: further epistemological problems

Efforts to promote the effective intermeshing of disciplines are further hampered by deeper epistemological – and political – problems associated with the terms "environmental sciences" and "sustainable development." This problem is particularly acute for the term "sustainable development".

Our growth and prosperity is currently based on fossil fuels and finite mineral resources such as metals, phosphate fertilizers, rare gases, etc. We will certainly pursue the means to find and extract increasingly rarer and more expensive resources with ever increasing fervor and cleverness. Fossil fuels and virgin mineral resources will never be renewable resources and sustainable development can be perceived to have an integrated growth concept that is not easily reconciled with a near stop to growth based on ending the consumption of finite resources such as fossil fuels and minerals. Conceptually, two questions frame sustainable development. First, what should we sustain? This requires a reflection on the intergenerational allocation of the resources and the nature of our bequest. Some argue that welfare or consumption should be maintained, while others propose that a given stock of environmental assets must be preserved. Nobel laureate Robert Solow suggests that we conserve a generalized capacity to produce economic well-being (Solow, 1993).

The second question, closely linked to the first, refers to the feasibility of sustainable development. Feasibility depends on the substitutability of natural capital and man-made capital (such as physical capital or knowledge) in production. The degree of substitutability is associated with either strong or weak sustainability. *Strong sustainability* implies that environmental assets and man-made capital are complementary in production, and often argues for the preservation of a given stock of natural assets. As Andersen (Andersen, 2007) suggests, renewable resources should be viewed as "money in the bank", which ensures their inheritance by future generations: capital is preserved and only the income generated is used. But, for depletable resources, strong sustainability is impossible when all generations are weighted equally. This is because a positive level of resource consumption cannot be sustained indefinitely. This is the "cake-eating" economy (Martinet, 2012).

Weak sustainability offers a more flexible approach. Weak sustainability proposes that natural capital can be at least partially substituted, allowing a given level of production to be maintained with the input of less and less natural capital and more and more man-made capital. Hartwick's rule proposes that the rent from the extraction of non-renewable resources must be reinvested in capital stock to produce an annual yield equivalent to the current extracted resource value (Hartwick, 1977). Weak substitutability is compatible with Solow's proposition to conserve a generalized capacity to produce economic well-being. It implies a lower dependence to the resource and makes sustainable development more feasible.

Normative understandings of the different forms of sustainability pose one problem for transdisciplinary collaboration. But even when we have a definition of sustainable development that is understood and agreed, there are a host of issues that researchers from different disciplines find difficult – in practice – to resolve. Economics tells us that the environment is a *public good*, which involves the thorny problem of the appropriate allocation of costs and benefits. The benefit of generating growth and the associated pollution is mainly private while the social (environmental) cost is shared by all. The result is too much pollution. Renewable resources that are openly accessible suffer from the same public good problem; the benefit of harvesting one more fish is private while the cost of overexploitation is shared by a whole community, or sometimes by the entire population. For renewable resources, the sustainability problem is linked to the *misuse* of the resource and not whether or not it can be renewed (Martinet, 2012). Generally, the public good problem justifies public interventions through regulations, taxes, subsidies, emission permits, etc. – and both environmental protection and sustainable development are usually predicated on the intervention by a public authority. It is also important to note that the public good problem can persist at the state- and global- levels, which tends to reduce countries' concrete initiatives towards reduction in environmental impacts (initiatives are costly for the promoting country, while reducing impacts benefits the whole planet). The questions that arise from deep sea mining are an example on a very large scale (UNEP-United Nations Environment Program, 2014).

Coupled with this, is the fundamental question posed by environmental scientists and economists as to whether our development has already been excessive. Many suggest that we already have overshot – or will soon overshoot – the carrying capacity of our planet. Viewed from this perspective, sustainable development is perceived by some as an oxymoron, "development" is associated with continuous growth from the perspectives of industry, economy, agriculture and consumption: eternal growth cannot be sustainable (Daly, 1990; Jackson, 2009; Robinson, 2004; Rubin, 2012). The only sustainable development that is possible is when the carrying capacity of an environment is at equilibrium or steady-state, i.e., either no growth or only the growth that is the result of improvements in the planet's carrying capacity or in technological progress. If carrying capacity has already been exceeded, sustainability demands a contraction in the consumption of environmental resources.

The perceived failure of "sustainable development", some of the misuses, inherent ambivalence and different understandings of the term (Mebratu, 1998; Mitcham, 1995) may have fueled cynicism within a community of experts in environmental sciences and resentment that their work is assimilated under this label. Anecdotally, we observe a prejudice against "sustainable development" because it is too often used in situations where environmental benefits are small or nil, and because it has been associated with greenwashing of corporate and/or government action. The result is that many actually oppose the term and do not support the reference frame of thinking (Lakoff, 2010).

For these epistemological and political reasons, we suggest that it is impossible to use the terminology of "sustainable development" as a unifying concept that includes all aspects of the environmental sciences.

Given that we define "environmental sciences" as the aspects dealing with environmental issues in the broadest context of disciplines and applications, and "sustainable development" as a conceptual framework where the welfare of the current and future generations is taken into account and where our current growth efforts must deal with an environmental

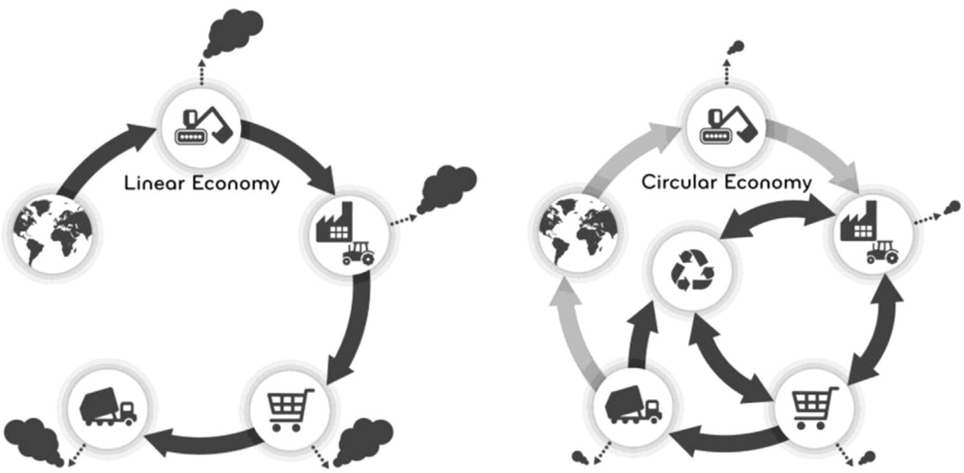

Fig. 1. Contrasting the linear and circular economy concepts. The economy takes place in a loop where the planet plays a key role in providing natural resources, and absorbing waste and pollution. The model holds as long as the planet's carrying capacity is not overshot. The linear economy (left) ignores the environmental impacts that come with resource consumption and waste disposal, and results in too much virgin resource extraction, pollution, and waste. Because the linear economy stays blind to much of the loop, it is often illustrated as a line, with a beginning and an end – from extraction to disposal where the potential returns to the Earth are lost through pollution. In contrast, the circular economy (right) takes into account the impact of resource consumption and waste on the environment. This creates alternative closed loops where resources are in circular movements within a system of production and consumption. The objective of the circular economy is to optimize the use of virgin resources, and reduce pollution and waste at each step, inasmuch as possible and desirable.

constraint, the question then becomes whether certain sustainable development approaches are more sustainable than others. This is where circular economy emerges.

4. An emerging concept: circular economy

"Circular economy" refers to a model of production and consumption that is fundamentally different from the "linear economy" model that has dominated society. The linear economy is based on a simple, linear process; extract, produce, consume and trash, with little or no attention to the pollution generated at each step (Fig. 1). The linear economy model is characterized by the primacy it gives to economic objectives, with little regard for ecological and social concerns (and internalization of these costs) as well as little reliance on related public policy interventions. However, the planet has finite boundaries, and even in the linear economy model of production and consumption, the wastes generated through extraction and production of the goods and the post-consumption products come around to haunt us as pollution as they eventually end up either in a landfill or are dispersed in ways that contaminate our environment.

The circular economy aims to decouple prosperity from resource consumption, i.e., how can we consume goods and services and yet not depend on extraction of virgin resources and thus ensure closed loops that will prevent the eventual disposal of consumed goods in landfill sites. Production and consumption also have associated "contamination transfers" to the environment at each step. In that sense, the circular economy is a movement towards the weak sustainability described earlier. It proposes a system where reuse and recycling provide substitutes to the use of raw virgin materials. By reducing our dependency on such resources, it improves our ability, and the ability of future generations to meet their needs. The circular economy makes sustainability more likely.

The idea of the "circular economy" is not new. It has its roots in a variety of "schools of thought" (see (Ellen MacArthur Foundation, 2012)) related to, for example, product life and the substitution of services for products (Stahel, 1997), cradle-to-cradle approaches, where waste becomes a value-producing resource (McDonough et al., 2003) and industrial ecology (Graedel and Allenby, 1995). What is new is the momentum that the concept is gaining among business practitioners (Ellen MacArthur Foundation and McKinsey & Company, 2014), policy advocates (Preston, 2012), and teachers (Webster and Johnson, 2010). Further, the concept is being adopted by governments in both Europe (see Bonciu, (2014)) and China (see Geng and Doberstein (2008)).

The increased attention to the "circular economy" concept is due, in part, to its capacity to provide the basis for reconciling the problem of how to promote productivity while considering the externalities of the production process, the consumption of the products and the end-of-life impacts. The circular economy promotes the production of goods through closed loop material flows and must provide the economic incentives to ensure post-consumption products get reintegrated upstream into the manufacturing process (Geng and Doberstein, 2008; Souza, 2013). In a circular economy, the consumption of raw virgin resources is reduced to optimize the use of by-products, wastes or recycling of discarded products as the primary source of resource materials and to reduce pollution generated at each step (Pinjing et al., 2013). In these loops, integrated combinations of industrial activities act synergistically to feed and be fed by one another. The by-products from one industry thus serve as resources for the next and energy consumption is shared for optimal use. In such eco-industrial settings, resource supply and waste assimilation are optimized.

The circular economy model promotes the resiliency of resources. It aims to replace the traditional linear economy model of fast and cheap production and cheap disposal with the production of long lasting goods that can be repaired, or easily dismantled and recycled. A model of production based on a circular economy may seek to extend the useful life of the product, i.e., delay its end-of-use. It favors the possibility of repair, refurbishment and reuse of products before their actual end-of-life (when it will be recycled into materials that become raw resources). The circular economy model aims to emulate processes similar to those that occur in natural environments, where little is wasted and most is recuperated by another species. Competition and cooperation among species occur in nature, thereby maintaining the efficiency of natural ecosystems and certainly providing flexibility and adaptability. Applying this metaphor to economic systems helps to ensure healthy competition and maximum efficiency of usage of available resources (Geng and Doberstein, 2008).

5. Circular economy and sustainable development: some epistemological problems

A significant difference between the circular economy and the linear economy is that sustainable development, when applied through the linear model of production, may emphasize waste reduction, recycling and reduction of pollution, focusing mainly on the downstream processes of production and consumption. The result can be that, in "linear" sustainable development initiatives, products that are recuperated through recycling efforts are too often orphaned; value chains are simply not in place and there are few actors who are ready to use waste as raw materials for new production. In particular, current manufacturing processes favor the use of virgin resources which are readily available in an easy-to-use form. In contrast, the circular economy model is clearly resource-oriented. The circular economy seeks to take into account all of the inputs and outputs of the production process, albeit with a significant emphasis on wastes.

Due to the fact that (as outlined above) experts do not agree on the notion of sustainable development, the ways that circular economy, linear economy and sustainable development are linked and compared can differ significantly. In particular, some specialists in environmental sciences perceive "sustainable development" as a set of initiatives that have been implemented within a linear thinking, thus for them sustainable development and linear economy have become inseparable. The circular economy therefore offers a solution where sustainable development, when implemented in a linear economy model of production, is perceived as a failure.

For some experts in other fields, such as environmental economics, sustainable development is a concept (or an objective) that remains independent from past unsuccessful initiatives and, more importantly, independent from the linearity of the production–consumption model. Sustainable development is a society objective defined at the macro-level and includes broad notions of ecological, economic and developmental (or social) sustainability (Bartelmus, 2013) while the circular economy approach is mainly defined at the micro-level through a model of consumption and production. If the application of circular initiatives brings better results towards sustainability, then the circular economy becomes a tool for sustainable development.

Under this framework, sustainable development and circular economy are respectively top-down and bottom-up approaches. But it is not clear if they meet mid-way. Sustainable development sets broad inter-generational objectives and, although it is often associated with the internalization of externalities and a set of policy instruments to do so in practice, the core concept of sustainable development stays silent on the manner to reach sustainability.

For its part, the circular economy comes with a set of tools that may be used for sustainable purposes, but the final objective remains unclear and certainly narrower than sustainable development. In particular, the circular economy puts the environmental sustainability forward, acknowledges the need for a favorable economic context (the circular model), but the social objective is usually absent.

The ambiguity behind the objectives embedded in the circular economy approach is fed by two phenomena. First, because of all the greenwashing that has been associated with the buzzword "sustainable development", many proponents of the circular economy approach will avoid references to sustainable development and, in turn, to its societal objectives. Second, there is the potential to believe that, if the circular economy principles are followed, a general welfare improvement will emerge, which could serve to justify the promotion of circular initiatives without the need to define specific normative (social) goals. To reconcile the circular economy and sustainable development, Andersen concludes: "The establishment of a future trajectory for a circular economy will require that this approach be extended so that the broader issue of sustainability can be addressed more comprehensively" (Andersen, 2007).

Sustaining the virtuous loops of production and exchange poses a particular problem because they eventually reach their limits. At some point, the extra cost of improving and refining further a circular material flow will exceed the corresponding benefits to society, and this is true for any kind of environmental protection. Specifically, a circular economy must promote loops when *socially desirable* and efficient (Andersen, 2007), i.e., as long as the benefit is greater than or equal to the cost. "Socially desirable" implies the definition of some normative goals to arbitrage between non-trivial alternatives, e.g. should we invest in a new infrastructure to recycle a specific material in order to reduce waste and preserve the resource, or should we keep exploiting the raw material at cheaper cost, use the short term benefits to build a school and educate our children? When is the benefit greater than the cost?

Other authors propose a gradation in the concept of circular economy, with the highest level, which includes societal interests, being very close to sustainable development. Using China as a case study, we can divide the circular economy into three levels of organization: micro, meso and macro (Geng and Doberstein, 2008). China, stimulated by the country's resource supply and environmental problems, has been one of the early adopters of the circular economy as a national development model (Geng et al., 2013; Lévy and Aurez, 2014; Yuan et al., 2006; Zhijun and Nailing, 2007). The micro-level of circular economy focuses on a particular firm or industry and is based on relatively standard sustainable development initiatives, applied through a linear thinking, such as reducing wastes and optimizing resources for a cleaner production that lowers its environmental footprint. The meso-level looks at interactions among different firms or industries where each benefits from the by-products of one industry as raw resources for its own production and is analogous to ecological industry concepts. Of course, the application of this approach in China is facilitated by governmental directives that set out the terms of an eco-industrial district and subsidize its implementation (Mathews and Tan, 2011; Zhijun and Nailing, 2007), which is then reinforced by local leadership (Lévy and Aurez, 2014). The third, macro-level of circular economy is related to social aspects. At the macro-level – and in contrast to the micro and meso levels – production and consumption become integrated. At the macro level, the incentives for circular economy must be phased in with societal and stakeholders interests. Under Geng and Doberstein's classification, this is where circular economy could meet with sustainable development.

6. Circular economy: some practical challenges

The complexity – and novelty – of the circular economy model raises a number of practical challenges that require experts from diverse disciplines, including the natural sciences, engineering, economics, and management, to address and resolve. To close production loops, the circular economy must provide the economic incentives to ensure that post-consumption products are reintegrated upstream into the manufacturing process. One of the hurdles that the circular economy faces is that it is usually more expensive to manufacture a durable long lasting good than an equivalent quick and disposable version. This is a public good problem: the benefits of producing a less or a non-durable good is private while the environmental cost is public. In particular, it requires changing the paradigm of the linear economy where the external costs related to a series of environmental and human health issues are dissociated from the production and consumption of the goods. Instead, these costs need to be fully integrated in the price paid by the consumers.

Theoretically, both the circular economy and sustainable development propose to internalize the cost of environmental damage in productive activities. However, the standard linear production model only makes partial attempts to do this when it comes to collecting and recycling waste. In contrast, the circular economy offers a more comprehensive approach (Bonciu, 2014), with each step in the production and useful life of the product, and its repair or dismantlement, internalizing both the cost of using new material resources and energy, and their release of contaminants that have negative impacts on the environment and human beings. By considering a fuller range of production and consumption activities, the circular economy prevents environmental burden shifting towards other activities. In that perspective, the circular economy helps to define what should be internalized and can therefore play a significant role in reaching sustainable development objectives.

Finding the proper ways to internalize the full environmental costs is certainly an important challenge for the circular economy. Measures must be put in place (e.g. take-back regulations, taxes, etc.) to ensure reverse flows of products post-consumption and close the loops when desirable (Pinjing et al., 2013; Souza, 2013). In this respect, however, the circular economy is no different from sustainable development. Both rely on intervention by some authority, which in turn depends on a set of political-economic issues – public good problems, externalities, open access, etc. – that go beyond the theoretical concepts. These types of barriers can slow down circular economy initiatives – and the circular economy approach will not be immune to failures, misuse, ambivalence and greenwashing. Nonetheless, the "circular economy" offers a conceptual framework that enables the development of contractual agreements between the users and providers of products and services that can better align incentives and lead to more eco-efficient uses of resources.

With that comes the need to re-orient consumer thinking towards assessing alternative products in terms of *functionality,* which dissociates the product from the utility it provides. In a circular economy model, consumers purchase a basket of functionalities to meet their needs. A given functionality can be fulfilled by a set of different options which includes the goods, their services and other alternatives. For instance, the need for transportation can be met through the consumption of individual cars, carpool or car-sharing systems, or public transportation networks. While the concept of functionality is simply another way of categorising substitutes, it may trigger ideas and initiatives where needs are met in ways that, in turn, generate virtuous loops in material flow, i.e. reuse, repair, remanufacturing, and so on.

A model based on "functional service" can shift the locus of product ownership. For example, there is an increased tendency towards selling services instead of products, the service providers sell the usage for a given period while they retain ownership of their products and the consumer is much less concerned with the performance, maintenance, upgrade or replacement of the goods. As property rights change hands, incentives linked to conception, quality, maintenance, update and disposal vary. For instance, if the service provider is also the producer, then the benefits of durability or reparability can be fully internalized at the product's conception stage. In this scenario, the business model spurs green design and encourages product reuse – clearly falling within the circular economy framework. Sharing services is another way to increase the efficient use of available resources and equipment. Our consumer thinking is excessively geared towards everyone having their own equipment in order to be independent, with the result that many products are only partially used. A refocusing on rental and shared-use offers the potential to improve the efficiency in use, as well as reduce the needs for maintenance and the needed space for storage (or car parking!).

Eco-design and life cycle analysis are important and related tools that enable a circular economy. Eco-design – which has many definitions (Prendeville et al., 2012) – can be briefly summarized as an approach where environmental considerations are integrated into the product design and development. But, there needs to be care in evaluating the options that might reduce environmental impacts in one stage of the life cycle of the product, but would increase these elsewhere. For instance, using raw materials that emit fewer atmospheric pollutants during the manufacturing of a product could lead to a more complicated recycling or reuse at the end-of-use or end-of-life. It may also be environmentally sound to replace a functional piece of equipment for a newer one with better environmental performance. Environmental gains in a specific life stage of a product should not be made to the detriment of impacts at other stages. A life cycle approach is therefore an indispensable tool of eco-design and essential to properly compare different options to be implemented within a circular economy approach.

7. Conclusion

Our aim has been to examine three different concepts that relate to the protection of the environment – environmental sciences, sustainable development and circular economy – and to explore some of the opportunities and challenges that each one offers in terms of transdisciplinary research. We stress that it is not useful to try to compartmentalize them, or to argue that one is inherently better than another. We seek to highlight the different perspectives as a means of clarifying both their meaning and the practical challenges that are associated with them. Nevertheless, we feel the circular economy concept is gaining momentum because it is giving a clear angle of attack to help solving environmental problems. Environmental sciences, sustainable development, circular economy and, indeed, other terms are all important to finding solutions for a better environment. The concepts (to some extent) – overlap, and researchers, guided by any or all of them, can certainty contribute to the protection and improvement of the environment.

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