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Methodological and Ideological Options

Eco-efficiency of Virgin Resources: A Measure at the Interface Between Micro and Macro Levels

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ABSTRACT

Eco-efficiency is often considered an adequate response to the problem of the scarcity of non-renewable resources. Even if a more eco-efficient use of natural resources cannot guarantee lower resource consumption, it can allow a better combination of desirable economic activity with undesirable resource use. However, more eco-efficient use of resources at the micro-level does not always lead to higher eco-efficiency at the macro-level. This is due to resource flows between actors at the micro-level. They use both virgin resources and resources that have been previously used. Virgin resources represent the relevant scarcity at the macro-level, while eco-efficiency at the micro-level typically does not discriminate between virgin and used resources. We develop an eco-efficiency formula that closes this gap. Our formula not only allows the measurement of the eco-efficiency of virgin resource use at the micro-level, but also helps to identify the drivers of the eco-efficiency of virgin resource use. Application of the formula to the case of gold in smartphones points to the very limited potential of technical improvements and shows that behavioural and collaborative endeavours promise dramatically higher improvements in eco-efficiency. This calls for a reconsideration of the focus of efforts to increase eco-efficiency for sustainable development.

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1. Introduction

Resource scarcity has been recognised as a limitation to human development for decades, if not centuries (Boulding, 1996; Green, 1894; Malthus, 1798). While resources are required for any economic activity, the depletion of non-renewable, natural resources threatens to limit the level of activity necessary to satisfy human needs. This means, that to both protect such scarce resources and satisfy human needs, economic activity must become more resource-efficient, i.e. the amount of economic activity per unit of resource used must be increased.

Discussions around this imperative have been associated with eco-efficiency in literature on sustainable development (World Business Council for Sustainable Development, 1996, 2000). Some approaches, such as the Eco-Efficiency Indicators (EEI) framework (United Nations, 2009), adopt a very broad perspective, with a relatively weak focus on the re-use and recycling of resources. Instead they propose quite general factors be used to both establish and improve eco-efficiency, including for example, 'the service intensity of good and services' (United Nations, 2009, p. 4).

Measures to determine changes in eco-efficiency performance can be distinguished according to two different foci: One which directs efforts to reduce/minimise resource use (DeSimone and Popoff, 1998; Schmidheiny and Business Council for Sustainable Development, 1992) and another which concentrates on the value created (Figge and Hahn, 2004a) to improve eco-efficiency. Both approaches posit that when a resource is used more efficiently, less is required to produce a constant level of economic activity. As Figge and Hahn (2004b) have shown, the two approaches are complimentary. Burden-oriented approaches seek to minimise burdens, for example by substituting more harmful substances with less harmful substances. Contrastingly, value-oriented approaches seek to maximize value creation, for instance by finding uses for substances that are more value creating. The two approaches therefore look for increases in eco-efficiency in different ways. Burden-oriented methods look for the reduction or substitution of burdens while value-oriented methods look for alternative, more value-creating uses. It is only when burden cannot be further reduced or value increased that maximum eco-efficiency is obtained.

Approaches in measuring eco-efficiency have generated different frameworks and metrics of analysis. ISO 14045:2015, for example, advocates Life Cycle Analysis (LCA), which unlike the EEI framework, is more specific in its focus. The general principles of LCA have more

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recently been developed by researchers to design more sophisticated frameworks (e.g. Arampatzis et al., 2016; Bach et al., 2016). Several others have sought more comprehensive tools of analysis by combining LCA with other methods. Lorenzo-Toja et al. (2015), for example, combine LCA and Data Envelopment Analysis (DEA) to determine the eco-efficiency of waste water treatment plants. Others have combined LCA with Life Cycle Costing (LCC). Burchart-Korol et al. (2016), for instance, describe how LCC enables a financial dimension in assessing eco-efficiency in the fossil fuel industry (see also, Czaplicka-Kolarz et al., 2015; Kicherer et al., 2006; Lorenzo-Toja et al., 2016).

Measures to track eco-efficiency performance do not, however, guarantee a reduction in the use of non-renewable resources and thus eco-effectiveness. Eco-effectiveness has been defined in different ways (see for example the discussion in Stahlmann and Clausen, 2000). Effectiveness in general and eco-effectiveness in particular refer to the ability to deliver an expected absolute outcome, i.e. environmental performance in the context of eco-effectiveness (Figge and Hahn, 2004a; Wang and Côté, 2011). Eco-efficiency cannot guarantee eco-effectiveness due to two, perhaps, connected reasons. The first is explained by Jevons' Paradox (Alcott, 2005; Jevons, 1866), or the rebound effect (Sorrell and Dimitropoulos, 2008). Here, reduced resource consumption, resulting from more efficient use in operational processes or products, can be overcompensated by growing demand for those enhanced processes and products. Such demand means that rather than *reduced* overall resource consumption, efficiency improvements lead to *increased* use of non-renewable resources.

The second reason is that eco-efficiency measures are not necessarily directed at dealing with the scarcity of non-renewable, virgin resources. Some of the measures above, for example, place more of a focus on products rather than their composite resources per se. In doing so, they do not distinguish between finite and non-finite resources. The earth's store of these virgin resources is finite (Boulding, 1973) and it is this scarcity which has to be targeted, and which some assessment methods also fail to do. Once a virgin resource has been removed from the earth's stock, it might be transformed and used a number of times in products or processes. Such repeated use and transformation can contain, to some degree, the amount of virgin resource required to satisfy demand (Ayres and Kneese, 1969). Indeed, in the ultimate scenario, those previously extracted, finite resources would be used repeatedly and no additional virgin resources would be required. In such a situation, the efficiency of resource use would be irrelevant because society would not be faced with resource scarcity. This state is sometimes referred to as a circular economy (Pearce and Turner, 1990). However, until such a scenario becomes reality, society has to direct its attention at preserving the earth's stock of virgin resources. Our interest lies specifically in the eco-efficiency of virgin resource use as a means to address this.

The inevitable need for virgin resources to support economic activity means that, despite their shortcomings, measures to track eco-efficiency performance are necessary. We contend that the value creation approach to eco-efficiency in relation to virgin resource use is an appropriate measure and one which can equally target scarcity. It is on this basis that we develop the propositions contained in this paper.

Developing the value creation approach to measure the eco-efficiency of virgin resource use presents two challenges. The first lies in understanding how value might be created while containing the demands placed on scarce, virgin resources. The second relates to being able to account for the fact that virgin resources will only represent part of the unit of resource used to create value.

In addressing these challenges, we note that while the ambitions associated with sustainable development are played out at the macro-level, many of the actions to improve eco-efficiency (such as creating more value per unit of resource) are undertaken at the individual actor level, that is to say at the micro-level. Some earlier work has recognised at least some relationship between macro and micro levels. Jennings and Zandbergen (1995), for example, posit that "individual organizations cannot become sustainable: Individual organizations simply contribute to the large system in which sustainability may or may not be achieved" (p. 1023). The difficulty of developing this idea lies in the absence of a means by which individual eco-efficiency actions can be connected to macro (or societal level) eco-efficiency performance, and ultimately sustainable development. Our new measure to determine the eco-efficiency of virgin resource use, not only makes this connection, but can also be utilised by individual parties to inform actor-specific decisions regarding eco-efficiency of the individual party, i.e. micro-level eco-efficiency. In summary, our central contribution in this article pivots on the development of a new measure to understand virgin resource use within an eco-efficiency context, and which connects micro-level behaviour to macro-level outcomes.

We apply our proposed measure to the case of smartphones, and in particular gold as a resource, to show how different actions impact eco-efficiency. Additionally, we show the types of actions which can contribute markedly to improved eco-efficiency performance. We draw implications from our illustrative application and suggest ways in which the measure might be developed further.

2. Sustainable Development and Eco-efficiency: The Disconnection Between Macro-level Necessity and Micro-level Contribution

If we consider eco-efficiency in relation to sustainable development, then we can conclude that this lies at the macro-level (Figge et al., 2014). "Spaceship Earth" (Boulding, 1973) would be the highest macro-level imaginable in the context of sustainable development. The term symbolizes that the earth's resources are finite and that sustainability issues are decided at a planetary level. This context drives the question as to whether we use the earth's resources in a way that allows society to survive. However, not all questions relating to sustainable development are scoped at this planetary level. Other manifestations of the macro exist that raise different issues. Considering regional spaces, for example, impacts such as ambient air pollution are a problem for some areas but less so for others, in terms of both cause (e.g. Xu and Lin, 2016) and effect (e.g. Zhou et al., 2015).

In this paper we do not define the macro-level narrowly, i.e. as residing on any one particular level as opposed to another. Instead, we scope the macro-level as a flexible concept, and present its meaning across multiple potential environments. In this paper, we focus on defining the macro as any context in which the attainment of sustainable development is considered. In contrast, we refer to the micro-level as any context in which there is an assessment of resource flow. This could include, for example, a particular process where resources move from one actor to the next. Other examples of micro-levels include industry clusters, firms, or individual people; indeed any 'location' which is assessed on its use and flow of resources.

By using resources more efficiently, micro-level economic actors might contribute to goals of sustainable development at the macro-level. But this is not a given. Fundamentally, the macro-level dictates whether resource use at the individual level is significant. For instance, individual actors might use resources inefficiently, but this is without consequence if, at the macro-level resource use is sustainable anyway. The converse is also true: Efficient use of resources at the micro-level is only meaningful if there is the possibility for sustainable use of resources at the macro. Simply put, the macro-level in this sense dominates the micro in the extent of influence the former has over resource sustainability. In this paper, we examine the relationship between micro and macro contexts, where resource flow is assessed at the micro-level, and where the macro is the location for conclusions made as to the attainment of sustainable development.

As a measure for sustainable development, eco-efficiency is a performance measure at both micro and macro levels (Huppes, 2007), yet much of its conceptualization and operationalization has been at the micro, i.e. at the level of the individual resource use or user. Eco-efficiency has, for example, been applied to processes (Li et al.,

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